BIBLIOTICS
OR THE
STUDY OF DOCUMENTS

FRAZER

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Chas J Hughes Jr

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STUDY OF DOCUMENTS

DETERMINATION OF THE INDIVIDUAL
CHARACTER OF HANDWRITING

AND

DETECTION OF FRAUD AND FORGERY

NEW METHODS OF RESEARCH

BY

PERSIFOR FRAZER

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TO

DR. EDWARD PEPPER

THIS WORK IS AFFECTIONATELY DEDICATED

BY

THE AUTHOR

From Preface to First Edition.

The first attempt to separate a branch of study from other cognate branches; to define it and to establish for it an individual existence, is not always successful. Any one man is likely to be too much influenced by his own point of view, and thereby to include too much or too little.

But any earnest effort will be attended with the result of directing other minds to the subject, so that if the object be worthy, its evolution will be aided, and if not it will be dropped. I have this conviction to fortify me for producing another book, and hope this subject will be given its final shape by abler hands if, as I believe, it has a reason for existing.

I have suggested Bibliotics as its name, because βιβλίον (book, sheet, scroll, libel at law, etc.) is broad enough to apply to any object which it may be desired to investigate, such as parchment, wax tablets, papyrus, printing-paper, stone, or, in fine, any substance capable of receiving and retaining characters. It will include hieroglyphics, writing, printing, or designs of any kind intended to impart specific information by symbols, in contradistinction to general impressions conveyed by art designs. It will include also the materials used to make

tracings, such as paint, inks, and other coloring matters. In a word, Bibliotics would include the study of the materials used in making designs for the transmission of intelligence, as well as the individual character exhibited in the designs themselves ; and though it is distinct from art conceptions, from literary or historical criticism, and from chemical and physical investigations, yet it accepts and needs the aid of all of these studies in obtaining its results.

It will follow that Bibliotics as such is not exclusively concerned either with the establishing of character or the discovery of fraud, but includes both subjects.

The first of these I venture to call Grammapheny, from *Γράμμα*, a writing, and *φαίνω*, I demonstrate. It is the elucidation of the individual character of handwriting; that by which it distinguishes itself from every other handwriting.

For the art of detecting forgery or fraud in documents, seals, writing materials, or in the characters themselves, I have suggested the word Plassopheny, from *Πλάσσω*, I forge, and *φαίνω*. This study is directed to any part of a written or printed or sculptured record, and makes use of all resources to test its genuineness, but by its very nature it cannot be expected to *demonstrate* genuineness except by exclusion in its failure to demonstrate fraud. . . .

PHILADELPHIA, June, 1894.

Translation of Extract from Note of M. Louis Vossion, the Translator into French of the Second Edition.

. . . "Whatever may be the profound and sometimes radically irreconcilable divergences of the experts called to testify before the courts, the fact exists none the less that these same courts could not to any extent do without them.

. . . "One of these two propositions is true. Either the testimony of witnesses has real and absolute value, and the establishment of truth will be facilitated by it, or the errors they [certain handwriting experts] would commit in their public demonstration, through ignorance, charlatanism, or even voluntarily, would be apparent at the first glance.

"Dr. Frazer's book defines . . . by . . . clear and precise methods the character in which the true expert should appear before the court; it is destined to aid in the attainment of the highest aim which judges and juries can have in view,—the discovery of the absolute, indisputable truth. . . .

"Paris, June, 1899."

PREFACE TO THE THIRD EDITION.

The author has completely rearranged, and very largely rewritten, the original book of which this is the third edition. The subject has been divided into:

PART I. *Physical considerations*, including the general physical examination and the physical tests to obtain light on certain special points.

PART II. *Grammapheny*, or the study of the individual characteristics of the writing.

PART III. *Plassopheny*, or the means to be employed for the detection of forgeries.

PART IV. *Chemical considerations*, including a statement of the constitution of the common inks, and chemical tests applicable to documents by means of which the nature of an ink may be ascertained.

He has endeavored to collect together the subjects which were out of place in the edition of 1894, and to include them in a rational scheme of classification. He has also tried to exclude from the book, as much as possible, all subjects not connected with the attainment of conclusions in the study of documents, and for this reason has omitted the chapter on the laws relating to the

testimony of experts in handwriting, which, at his request, Mr. J. Douglass Brown, Jr., kindly contributed to in the first edition, as well as all allusions to judges, juries, witnesses, or trials, so far as this seemed judicious; for the book is intended as a manual for the study of the means of applying scientific principles to the investigation of practical problems concerning documents, and not for mastering the intricacies connected with getting conclusions in legal form before the courts. For a similar reason he has selected for illustration as little as possible the exhibits in *causes célèbres*, but has drawn on past history for individuals and incidents (witness General Washington and the Junian controversy) rather than the exciting topics of the day; the latter selection being open to the suspicion of sensationalism if not self-advertising. An exception has been made to the exclusion of discussions of evidence, in that part of the Appendix wherein is mentioned the effort of the Pennsylvania bench and bar to frame a general law governing the testimony of experts in the courts. This was done because the subject is a broad one; because it is occupying the attention of the educated people of Pennsylvania, and of other States and countries; and because the points of view seemed new.

Shortly before the first edition of this book was published the law regulating the testimony of handwriting experts in Pennsylvania was that laid down by Chief Justice Woodward, in Travis *vs.* Brown, of which the summary is given in the Appendix. This opinion, how-

ever, was so variously interpreted that in three counties of that State and on three successive months three contradictory and incongruous decisions were given by as many judges. The last was the *reductio ad absurdum*, for it declared that if any person had even seen writing alleged to be by the hand of the person whose writing was in dispute, such person was incompetent to testify as an expert. Further, that the only opinion which an expert was authorized to express was whether a given piece of writing were in a simulated hand,—an absolutely impossible task where no genuine writing may be used for comparison. This state of things seemed so unsatisfactory that the author drew up a sketch of a law which was put into legal phraseology by Mr. E. P. Allinson, approved by several judges, and finally presented to the Legislature by the present United States (then Pennsylvania State) Senator Boies Penrose, passed unanimously, and signed by the then Governor (Hastings). The text of this present law will be found in the Appendix after that of the summary of Judge Woodward's opinion.

* * * * * * *

The author was induced to commence the study of the characteristics of handwriting over twenty years ago through the misunderstanding by an attorney of the difference between experts on the physical and chemical properties of exhibits, and experts in chirography. In the foot-note, page 204, allusion is made to an examination of the first kind which he had made in the course

of a celebrated trial. Shortly afterwards an attorney, who was aware of his connection as an expert with this trial, desired him to reach an opinion as to the authenticity of certain signatures. He protested his inexperience in this kind of work, and only after the failure of the lawyer to secure the services of any professional handwriting expert, consented to make the attempt by an application of Francis Galton's ingenious discovery of composite photography. The experiment of making a composite of a number of signatures was successfully tried, explained, the result submitted to the court, and the unique experience achieved of bringing conviction not only to the mind of the judge but also to the minds of the attorneys on both sides, in spite of the witness's assertion that he was not a handwriting expert.

From his studies in this case the possibility of applying purely scientific methods to these difficult questions, and raising the whole subject above empiricism (and charlatanism) seemed manifest, and much of his leisure time since 1879 has been spent in endeavors to discover and perfect such methods. The pictorial resemblances, the unusual method of making parts of certain letters or words found in every writing when closely examined, which constituted almost the entire foundation of handwriting expertism in the past, is not neglected, but is relegated to a subordinate rôle. They will always be valuable for suggestions and confirmations of other and more important tests. Indeed, if half a dozen or more of these superficial peculiarities be found con-

stantly in all writings by a given hand, it will be next to impossible for a forger, even if he saw them all, to reproduce them together in a manner indistinguishable from the hand to which they were acquired habits. Only multiply sufficiently the trifling divergences from the normal, and they will form an insurmountable barrier to producing imitations which must be executed naturally and simultaneously. Unfortunately it is not always, nor even frequently, that enough well-marked peculiarities can be found. And even although an expert forger may not be able to make a signature containing all the characteristic peculiarities quite as natural as the genuine, this will be a matter of opinion, and the discrepancies may not be great enough to carry conviction that the writing is not genuine. But it became apparent soon after the serious study of the subject was commenced, that the method of composite photography, though admirable for the purpose of establishing a standard of genuine writing, was frequently inapplicable, owing to the restricted number of specimens of authentic writing available, the expense, and the lack of time afforded to obtain this ideal standard. Besides, when obtained, it was but a standard with which the real work of investigation must be begun. Other methods were successively sought and found to supplement composite making, and the first of these was that of measurements, averages, and ratios.

By this method the essential characteristics of handwriting are elicited; those which a writer cannot help

introducing and no other can imitate. Such are the relations in length, height, and angle to each other and to the whole, of parts of a collection of words; of one word; or of one letter; discussed under the chapter on averages and ratios. It is an additional and most important advantage of this and the method next to be discussed, that the number of elements which may be used for ascertaining the genuineness or non-genuineness of the writing is almost without limit, while even in the most favorable cases the superficial characteristics are few and cannot be increased at need.

But there are occasions where the marks to be investigated are so simple in character, or so few, or vague, that the deductions from averages and ratios, though theoretically without limit in number, do not attain a desirable definiteness. When this is so, the microscopical examination of the ink lines will usually render great assistance.

The author was led to investigate the curious irregularities visible under sufficient magnification in the ink lines of writers in an important case,[1] and obtained the results stated in Chapter X. These fringes of ink lines have been heretofore neglected as a means of identification, and generally regarded as derived from some peculiarity of pen, ink, and paper, without reference to any personal influence of a writer. On closer inspection, however, it became evident that there is a

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[1] The People *vs.* Roland B. Molineux, New York, 1898–99.

certain uniformity in character of the irregularities visible in the writings of any given person, though not enough to identify him, so far as at present known. The phenomena to be observed are the general preponderance of the serrations of medium size at a magnification of about one hundred and twenty diameters on one side or the other of the *down-stroke* ink line. The up strokes and horizontal strokes also show similar features, but with somewhat less regularity, and to eliminate as many as possible of the already numerous unknown variables, only the down strokes have been considered, because in these strokes the action of the pen is most simple, and the causes of deviation most easily ascertained. The superficial appearance of these serrations changes with different ink, pen, and paper, with different moods and degrees of health, without losing a certain type character. But the general preponderance in number of these serrations on the one side over the other, or their nearly equal division between both sides; their comparatively constant distribution, and general character, seem established, from the observations which the author has been able to make, up to the present time.

With regard to the experiments and illustrations of the characteristics observable in the down-stroke pen and pencil marks of an individual, the author desires to state clearly that in his opinion the subject is too new and too important to treat otherwise than with the caution observed in Chapter X. If, indeed, every

down-stroke mark of every individual contain characteristics belonging at least to a limited class including him (and possibly even some characteristics peculiar to the writer alone), the fact can be irrefutably established only after a much greater number of experiments than the author has had the opportunity to make. At the same time, in his judgment and that of several experienced observers to whom he has submitted his work, the facts elicited speak with almost convincing force in favor of the existence of a constant general character in the irregularities observed. No hypothesis of chance variations, owing to the state of the writer or the kind of writing materials, will account for all the phenomena, and the probability is greatly in favor of the view that most of these irregularities are derived from the writer. If so, they can be made at least the means of aiding in his identification. The reluctance of the author to take a more decided stand on the question at the present time is due to the fact that he is not proficient in the studies which must be relied on finally to settle it,—*viz.*, physiology and experimental psychology. The verification or refutation of his provisional conclusions must be left to physiologists and psychologists. Fortunately, Dr. Charles S. Dolley and Professor Lightner Witmer, experienced respectively in these sciences, have examined the subject, verified the observations of the author, and are in perfect accord with him as to the fact that the serrations and microscopically small sinuosities are derived from unconscious movements of the writing-hand.

On this subject Dr. Dolley says, in answer to a question, "I think the serrations and sinuosities are largely due to fluctuations in nerve force, while the alterations in width may, to some extent, be due also to variations in blood-pressure in the hand." (This latter is simply another manifestation of fluctuating nerve force.)

The methods of investigation original with the author, and described in the text, are the following:

1. The method of determining the order of sequence in lines which cross each other, by oblique illumination and vision. (Page 58).

2. The method of discriminating between and defining inks by their respective actions on light transmitted successively through variously colored standard prisms devised by the author. (Page 88 and Appendix.)

3. The employment of portions of down-stroke pen and pencil lines under sufficient magnification by the microscope, to aid in the identification with, or separation from, other writings. (Page 97.)

4. The application of composite photography for the purpose of obtaining the most accurate standard type of a given mark, word, phrase, and especially signature, often repeated by a given writer. (Page 109.)

5. The use of measurements and numerical averages of parts of sentences, words, or letters, and the determination of the ratios of such parts, for the purpose of ascertaining whether two writings show the same evidences of certain acquired habits. (Page 132.)

6. The partial analysis of a handwriting, made by joint efforts of two hands, into its component parts. (Page 152.)

7. The characteristics of marks made when the writing instrument is touched by a hand other than that holding it. (P. 162.)

The author's personal thanks are due to Dr. George H. Hallett and Professor Lightner Witmer of the University of Pennsylvania, and Dr. Charles S. Dolley of the Philadelphia Central High School, for the interest they have manifested in his work, and the encouragement which their confirmation of his conclusions has given him. Dr. Hallett has contributed a very interesting mathematical demonstration of the applicability of the author's standard colored prisms to the determination of the absolute absorptive power of inks for various colors referred to a standard white light.

Professor Witmer and Dr. Dolley have repeated with him many of the observations recorded in the chapter on the examination under the microscope of down-stroke ink and pencil lines, and confirm their accuracy and the author's conclusions; the former furnishing in addition specimens of handwriting by himself and others for illustrations to the book.

To Professor Samuel P. Sadtler the author is indebted for many valuable suggestions and for reading the proof of Part IV.; and to him, Professor Henry Krämer, and Dr. Harris A. Slocum, for examining under the microscope and tracing by camera lucida, in conjunction with

the author, specimen pen-marks; and to Professor Arthur W. Goodspeed of the University of Pennsylvania for reading and endorsing the presentation of the physical part of the determinations by means of the colored prisms.

The foot-note on page 103 was intended to remind readers unfamiliar with the microscope of the total reversal of all parts of the natural object in the image formed on the retina; but as this general statement might be misunderstood to apply to the camera lucida tracings, it should be added that the prism used in making these tracings restores the top and bottom of the object viewed to their proper positions, leaving the right and left sides interchanged.

After this book was printed, Dr. S. Weir Mitchell, who expressed great interest in the subject of the ordinarily invisible tremors in handwriting, sent the author two pamphlets by Augustus A. Eshner, M.D. ("A Graphic Study of Tremor," from the *Journal of Experimental Medicine*, vol. ii., No. 3, 1897; and "A Case of Congenital Tremor," from *Medicine*, May, 1897), describing experiments in which tambours held in the hands recorded on a rotating drum the fluctuations of pressure with forceps or with the fingers and thumb. The amount of pressure varied from one to four ounces. These experiments, according to Dr. Eshner, record only

that movement which the author has called vertical, and it is gratifying to the latter that his only estimate of their frequency (p. 106), from the assumed space passed over by the pen in a unit of time (*i.e.*, six per second), agrees closely with the average of the "tremograms" very carefully and accurately taken on the kymographion by Dr. Eshner (*i.e.*, 6.7 per second). But the lateral movements, which are both much more frequent, and much more important in imparting distinctive character to the pen-marks, were not measured.

The author has specifically disclaimed any intention of discussing the physiological causes of these tremors, visible only under high magnification. It is sufficient that they originate in the body of the person making the marks; therefore, wherever, in this book, the expressions "nerve force," "nerve disturbance," "nerve impulse," etc., occur, he requests his readers to discard the noun "nerve," and read simply "force," "disturbance," "impulse," etc. Thus avoiding any appearance of pretending to a knowledge which he has not, this omission will hold the subject aloof from the supposed art of reading character in pen-marks,—"graphology."

If, in addition to that conviction of the human origin of the greater part of these serrations, which is derived from the experiments and illustrations given in these pages, one desire the reinforcement of authority, the following letters from my honored friends Dr. Horatio C. Wood and Dr. S. Weir Mitchell will supply the highest.

Dear Professor Frazer,—I have made no experimental studies concerning handwriting, but it seems to me positive that the various serrations, etc., must be at least in part due to involuntary movements. Tea, coffee, strychnine, alcohol, cocaine, etc., so enormously affect the nervous centres, and consequently the involuntary movements, that only long study can show how far these movements are really characteristic of the individual and how far they are affected by moods and other bodily states. I would undertake to produce violent tremors in the steadiest hand, provided the possessor of this hand would do as I directed.

Yours, etc.,

H. C. Wood.

December, 1900.

Dear Doctor,—After reading your study of pen-marks, I am well satisfied that the lateral irregularities are due in large measure to causes which belong to the individual neuro-muscular apparatus of man. Of course, as you have also shown, there are external physical influences which have their effect.

Yrs. truly,

S. Weir Mitchell.

Dr. Frazer.
December, 1900.

December, 1900.

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INTRODUCTION.

The following pages cannot pretend to meet all the wants of the student of handwriting, but they may be found useful for reference, and to suggest means which might be overlooked of attacking a problem.

Although the subject of which the little book treats has claimed the attention of civilized man ever since there have been records traced in characters and committed to the custody of guardians, there has been no comprehensive treatise on the subject known to the author of this book. Here and there in the technical journals articles have appeared on one or more subdivisions of this heretofore unnamed study, which for the want of a better word may be termed *Bibliotics*, or the study of the essential characters of documents, but no attempt has been made to classify it as one subject and to put its branches in their proper places.

Under the general head *Bibliotics* come, in order, *Grammapheny*, or the determination of the specific character of a handwriting, and *Plassopheny*, or the detection of forgery or falsification in either writing or documents.

Grammapheny is that investigation which aims to extract from a sufficient number of characters written

by the same hand the type which is the result of the physical structure and habits of an individual, and by which that writing is distinguished from every other.

It is not uncommon for questions of the greatest interest to attach themselves to such a determination totally apart from any question of fraud or forgery.

As instances may be mentioned the investigations of the handwriting of the letters of Junius.[1] A novel and equally interesting problem in connection with a case of double consciousness, involving a difference between the acts performed in one state from similar acts performed in the other, was submitted to the author by Dr. S. Weir Mitchell, of Philadelphia. It consisted in the comparison of two different handwritings corresponding

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[1] The reader may need to be reminded that in 1769, in a London popular newspaper called the *Public Advertiser*, conducted by one Woodfall, an anonymous letter appeared attacking the government. This letter was followed by some signed Junius, which were continued till January 21, 1772, and others, evidently by the same author, signed "Julius" and "Brutus," the writer having probably adopted the names of the second known of the plebeian family, whose surname was given to him on account of an apparent dulness, feigned to escape the fate of his elder brother. These letters created immense excitement, and every effort was made to discover their author, whose identity, in spite of the publication of "Junius identified" by Mr. Taylor in 1816, and the positive convictions of Lords Stanhope and Macaulay, remained uncertain until Mr. Twisleton's admirable work appeared, in 1871, which sets all doubt aside.

respectively to the two different mental states of Mary Reynolds.[1]

These studies are directed to the establishment of the peculiar features of symbols conveying ideas and traced on some permanent substance by hand. Their inherent peculiarities of structure depend upon the organization, will, and imaginative power of the person who has written them, but they are not to be confounded with the fanciful deductions of *graphology*. The patient analysis of the elements of characteristics in handwriting differs from graphology as craniology differs from phrenology, so-called; astronomy from astrology; or the study of finger-prints from palmistry.

Plassopheny is concerned with questions of the opposite kind,—*i.e.*, with the detection of characteristics in documents or writing inconsistent with their ostensible origin, and therefore with the assumption of their genuineness. The demonstration that the paper or ink of the document could not have been obtained at the given date of the document; or that the characteristics of the handwriting are incompatible with those of the genuine handwriting of the supposed writer, are illustrations of the field of *Plassopheny*. It will be remarked that so far as this latter investigation is concerned, its conclusions must be based upon a preceding establishment of gen-

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[1] Mary Reynolds: A case of double consciousness, by S. Weir Mitchell, M.D., Transactions of the College of Physicians of Philadelphia, April 4, 1888.

uine characteristics, which is the province of *Grammapheny*.

The method of pursuing these investigations in the past has been similar to that in judging of works of art. The question has been addressed to the unaided eye, and to the judgment fortified only by subjective impressions, as to whether certain marks, or symbols, or groups of them, were like or unlike.

That admirable specimen of honest, painstaking work by the Hon. Edward Twisleton, assisted by Messrs. Charles Chabot and Frederick George Netherclift, exhausts the subject of the comparison of the writing in the letters of Junius, the writing of an anonymous note, and the writing of anonymous verses to Miss Giles, by this old method; and seems to connect Sir Philip Francis indubitably with the first two, and Richard Tilghman, of Philadelphia, with the last. But to do this it requires 289 pages of large quarto form, thickly strewn with cuts and engravings, and whole pages of facsimiles, not counting 266 plates containing all the letters in controversy, and many others which bear upon them: yet in the whole work only the pictorial, or least essential, features of the writing are considered. One is struck with astonishment at this wealth of illustration, this unstinted generosity of plates and text figures; but one is tempted to ask whether the conclusions finally reached might not have been attained in a much less tedious and expensive manner.

The author, while modestly keeping his share of the

joint work in the background, says,[1] "Still, although Mr. Chabot has written his reports under professional responsibility, and they thus deserve to be read with more than ordinary attention, he is desirous—and I publish his reports with the same desire—that his conclusions should in no respect be accepted on grounds of mere authority, but that they should be judged of entirely by the reasons which he advances in their behalf. It is important to bear this in mind, for it is the practice of inferior advocates in courts of justice where evidence on handwriting is given contrary to the interest of their clients, to indulge in rhetorical declamations against experts; and the same practice is sometimes adopted by others who have not the same excuse for desiring to avoid rational discussions."

Taking it all in all, the text of Mr. Twisleton's contribution to the volume is among the most thoughtful and valuable contributions to the subject of expert testimony which the author of "Bibliotics" has seen.

When there is presented before a court of law a document concerning which it is important to know whether the body in part or whole, or the signature, or both are in the handwriting of some person whose writing or signature appears in other exhibits, the counsel on each side usually seeks the aid of one or more handwriting experts.

Commonly a teacher of writing or a paying-teller of

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[1] Preface, p. xiii, third paragraph.

a bank is preferred. It must be confessed that there seems good reason for the latter choice, for the man upon whose immediate judgment as to genuineness of signatures depends the safety of a bank is likely to have gained much experience and quick discernment of any suspicious circumstance. Moreover, he is not to be easily deceived in the cases coming daily before him. Yet how much the average paying-teller depends upon the trifling circumstances attending the presentation of the cheque, the appearance of the person presenting it, the probability of the drawer inserting such and such a sum, etc., becomes apparent when one has heard a number of these useful officers testify in cases where they are deprived of all these surroundings, and required to decide whether a certain writing is by the same hand which produced another writing, both being unfamiliar to them. In such cases, being obliged to create a familiarity with the signatures of a man whose character and peculiarities they have never known, they miss the aid of some feature, such as a dash, a blot, or the distortion of a letter which would recall to them the identity of the writer. Most of the best experts of this class confess that they cannot tell on what their judgment is based. They simply think that the writing is or is not by the same hand as that admitted to be genuine. But these witnesses are more likely to be right than the more pretentious professors of pot-hooks and hangers.

The case is analogous to that of the determination of a mineral species. There are many persons who, in spite

of a lack of knowledge of chemistry and crystallography, can readily determine a mineral species by looking at, and handling a fragment of it. There are others more versed in book knowledge, who can write the formulas of most mineral species on the black-board, and repeat from memory the characters which each of these minerals should show, but who are very inferior to the first named in actually detecting and naming a fragment at sight. But if the identification is important, involving the disposition of money, or the establishment of a principle, recourse is had to the chemist, who determines, by careful experiments and complex processes in his laboratory, the real constituents of the substance. From his results there can be no appeal except as to the accuracy of his work and the soundness of the conclusions he has drawn from it. Yet this analyst may be very inferior to the first observer in power of instantaneous determination, and to the second in book knowledge of minerals.

Nevertheless, so deeply seated has been the conviction, in bench and bar, that the only means of discovering a forgery is by comparing an undefined ideal in the mind with the writing in question, that in an opinion by Chief-Justice Woodward in 1862, reviewing the law in Pennsylvania as it then stood, this is expressly so stated.[1]

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[1] This opinion settled the procedure in all cases involving the examination of experts in handwriting down to May, 1895, the date of the passage of the present law, sketched by the author, which will be found in another place.

It has occurred more than once in the writer's experience that papers have been handed to him, while on the witness stand, with the demand that he should state whether or not they were forgeries, and although he has always protested that this kind of guessing is a mere waste of the time of the court, the presiding judge has occasionally insisted on compliance. It would be as reasonable to hand to a witness a piece of a cast-iron bar and require him to state, by inspecting it, how much phosphorus it contains, and whether it was run from the same furnace as another specimen.

The fundamental idea of an analytical investigation implies a careful and laborious study of all the facts by the use of instruments, and by the aid of methods which cannot be employed in a court-room. Within reasonable limitations the more rapidly an opinion is formed the less value it has on this as on all other subjects.

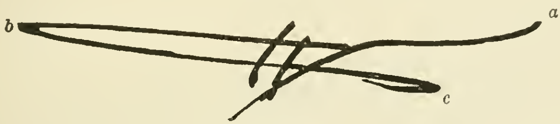
The procedures suggested in the following pages require a place where observations can be carried on without surrounding distractions, instruments suited to the investigation, and plenty of time to make them. The court which requires an expert, who bases his conclusions on this class of work, to resort to the practice of guessing, clearly oversteps its privileges and does a wrong to the witness.

While considering the subject of expert witnesses the necessity of extreme caution in forming conclusions cannot be too strongly emphasized. The first legitimate conclusion which is likely to be reached in the course of

discovering a fraud is merely that the document is suspicious, or cannot be proved to be genuine. Every contingency which the experimenter can think of should be invoked to explain away a circumstance seeming to suggest the theory of fraud. Where a number of unlikely hypotheses must be assumed in order to explain the appearance, they will ultimately force the conviction of falsification, and this conviction is less liable to be changed if it has grown steadily in spite of all attempts to avoid it.

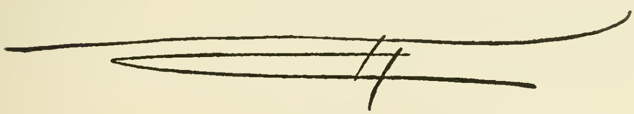
On the other hand the following flourish line is an illustration of the necessity of caution in forming conclusions.

Fig. 1.



Upper sheet.

Fig. 2.



Lower sheet.

It occurred under a signature in the ordinary way. The writing was done on two sheets of paper separated by a sheet of carbon paper inserted for the purpose of making a duplicate. The stroke was made rapidly and with some force, as was the custom of the writer. When the sheets were separated and examined, his surprise was great to find the lower flourish (which is the

lower in the accompanying illustration) entirely different from the upper one as to the direction of the line. Whereas the first stroke from right to left on the upper flourish turned downward abruptly, in the carbon copy it continued parallel to the edges of the paper. The only possible explanation is that in making the flourish, *a*, the pen-hand must have adhered to, and turned the upper sheet on the back of the carbon paper nearly at right angles to its former position; and the upper sheet must have come back to its place before the second stroke and the final vertical dashes, *b*, were made. The final horizontal loop of the second stroke in the upper sheet, *c*, was not repeated by the carbon paper on the lower sheet.

If an important issue had depended upon proving that the carbon copy was made by the same hand and at the same time as the upper writing, this non-agreement of the two flourish lines would very likely have been fatal to the establishment of what was actually the fact.

PART I.

PHYSICAL CONSIDERATIONS.

CHAPTER I.

INDIVIDUAL CHARACTER.

The Manner of Writing.—For the purpose of this little work it is sufficient to consider the art of writing as practised by most civilized western nations. But the principles involved are equally applicable to Sanscrit, Hieroglyphics, Japanese, Chinese, Persian, or Arabic, independently of whether the significance of the symbols be understood.[1]

In ordinary writing the page is laid on a support, usually near the edge of a table, and the hand holding the pen is laid either on or immediately below the edge

[1] It is difficult to understand the force of the explanation given by Lords Eldon and Kenyon of the former exclusion of expert testimony on handwriting in common law [see preface of Hon. Edw. Twisleton, of Report of Chabot, etc., on the writings of Junius, p. lix], "because of the inability of some of the jury to read." It is not at all necessary that they should be able to read in order to fully satisfy themselves of a forgery ; nor would their ability to read enable them *ipso facto* to detect a forgery.

of the paper. The elbow, some part of the forearm,[1] or the side of the hand is generally used as a pivot, and the hand somewhat bent, while the pen, supported by the fingers, moves across the paper from left to right, the fingers in the main producing the movement of the pen up and down, and the wrist, forearm, or shoulder giving the lateral motion necessary to execute any desired mark requiring a longer excursion than the fingers can perform.

Fig. 3 represents the ordinary position of the arm in the act of writing, *i.e.*, with the support and pivot at some point between the elbow and wrist; a skeleton arm being selected in order to show the positions which the bones assume, and to draw attention to the fact that an essential part of the character of handwriting depends upon the habit of placing a particular part of this rigid structure on the table as a pivot around which, as a centre, the writing is traced. Habit enables the writer to prevent the appearance of a curve in the line of writing by compensating movements of the fingers. Every time the pivot is changed the pen is naturally raised from the

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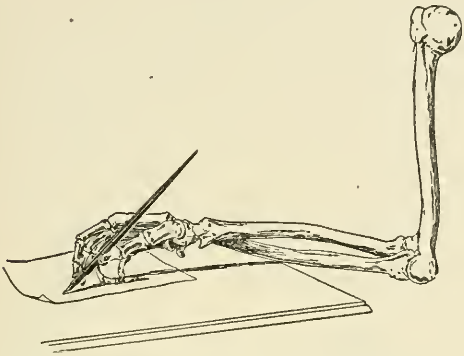
[1] "The forearms and not the elbows should rest upon the desk. The pen should be passed across the paper by a movement of the wrist and not of the arm."—A Manual of Handwriting, etc., by F. Betteridge, London, 1887.

It should be borne in mind that the author of these pages has no intention of attempting to instruct in the proper manner of writing, but merely wishes to represent the principal methods which are actually employed, whether they be faulty or not.

paper, and therefore the number of times the pen is removed from the paper will in great measure depend

Fig. 3.



upon the length of the radius between the point of support and the point of the pen. In Fig. 3 the hand could write entirely across the note-paper page represented without curving the writing, by shifting its position once or twice, but it would not be easy to write fluently without such changes.

Fig. 4.

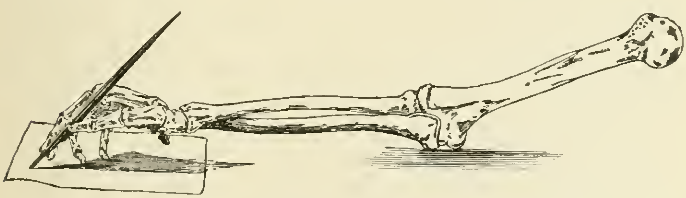
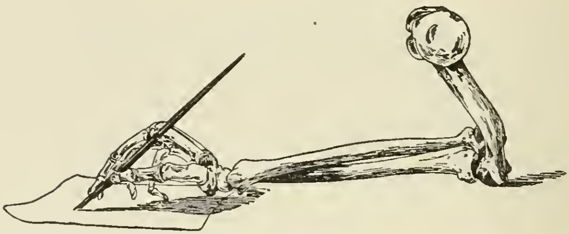


Fig. 4 represents the arm pivoted on the elbow, thus increasing by half the length of the forearm the radius of lateral motion, and rendering fewer changes of position of the pivot necessary. Handwriting of experts in

calligraphy is often made in this way. It permits a greater range of motion and allows more paper to be covered without removing the pen.

In Fig. 5 the elbow, forearm, and wrist are all in contact with the table, and the range of free motion without change of position is as small as it can be. In this attitude it would be necessary to shift the arm contin-

Fig. 5.



ually at the conclusion of every one or two words traced on the paper. It is the position naturally assumed by those writing with a board on the lap, in bed, or on a very high table.

Of course these are but three of innumerable positions which may be assumed by a writer, but they are, perhaps, the most common.

Some writers who are obliged to sign their names very often, or who act as paying clerks in large mercantile establishments, write the few words continually demanded without touching any support at all with the hand or arm. Some pivot the wrist on the top of the table, others hold the pen in an unusual position and

bring different parts of the hand in contact with the paper. But however a man may write, if his style become a habit, it may be reduced to the elements of a fairly constant pivot and radius, and certain methods of using the fingers, altogether giving a character to the writing which may be detected wherever it is seen.

Position.—The hand soon moves so far along the paper that a new position must be taken by that part of the forearm or hand used as a pivot. This fact, together with the individual peculiarities of every bony structure, and the very different methods which different persons employ to avail themselves of it, is of importance in studying the results of these efforts in a page of writing or a signature. These will be more fully referred to hereafter, but it may be generally mentioned that some writers move the forearm at the end of every two or three letters, while others attain the power of compensating, by larger excursions of the fingers, for the naturally descending curve of writing traced by the pen.

The same peculiarities are noticeable in the manner in which the pen is lifted from the paper: some writers, and usually those who have a great deal of writing to do, lifting the pen only when the pivot must be changed, and others fashioning each letter separately and often leaving spaces between the individual letters of a word as large as between separate words. This latter habit is commonest among those who have little writing to do, and among the aged or infirm.

Contraction of Habits in Writing.—These peculiarities, as well as the shading of the letters, and the hesitating or determined manner of making dashes, dots, and flourishes, are all connected with the temperament of the writer, and have been made the subject of study with a view of reading his character by his handwriting.[1]

Of all the above, the manner of changing the pivot in writing is the most important object of preliminary study, because, when the points of change have been ascertained, the general slant or slope of the letters and the angles of the different parts of a single letter with the general direction of the line of writing may be more easily understood, and form an important guide for establishing the genuineness or non-genuineness of the writing.

The parts of a writing which demand the closest attention are those which have been made most unconsciously and which are not noted by a superficial view.[2] The height, the spread of the letters, the peculiarities of the endings, the flourishes, and the general shape are features which the forger observes and imitates, often with success; but the curvature of a letter in its different parts is not so easily appreciated by the naked eye,

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[1] See The Philosophy of Handwriting, by Don Felix de Salamanca, etc.

[2] Of course, the hidden relations to each other of parts of a word, signature, or phrase, often repeated, and still more the very minute deviations from a general direction seen only under high powers of the microscope, which form separate subjects of a subsequent part, are not alluded to here.

and cannot even be easily traced without showing under a magnifying glass distinct signs of hesitation and labored effort very unlike the unconscious freedom of genuine writing.

The peculiarities of the angle with the horizontal, and of the unconscious rise and fall of the lower extremities of the letter with reference to a real or imaginary line drawn from the beginning to the end of the word or words, and sometimes called a "base line," and habits of shading or amplifying parts of letters too small to be seen by the naked eye, are tests of value which can be applied with the aid of a simple horn protractor and magnifying glass, but which generally elude the scrutiny or evade the successful imitation of expert forgers. But there are variations from the general direction in the separate parts of all long lines which come to view in such examinations under the microscope, and these must ever defy imitation on account of their extreme minuteness, though they are fairly constant. They will be more particularly mentioned in another place. It is to these peculiarities, inappreciable to the naked eye, and yet very constant in the pen or pencil marks of every writer, that the expert should give his most careful attention.

It is often asserted that tracings of a genuine signature invariably show hesitation and painting. This is not always the fact. Tracings proven, and subsequently admitted, to have been such have shown an apparent absence of all constraint, and a careful examination has

revealed no pause of the pen. But, on the other hand, these freely written tracings have almost invariably shown deviations from some habitual characteristic of the writer. Moreover, the greater the skill with which the model was followed, the more certain are two or three such tracings, when photographed on transparent films and superposed, to show such close superficial resemblances as to proclaim their character at once.

In addition to the visible deviations from the general direction of an ink line traced by a pen, are various others indefinitely more minute which are characteristic of each writer, and have been already alluded to.

Evolution of an Ideal Pattern.—The natural tendency of man is to introduce some elements of symbolism in what he is obliged to copy, and to seek some sort of geometrical symmetry in what he designs. Wherever he is not too much hampered by certain forms which he must introduce, and which may render a balance of parts about a median line unattainable, he tends to evolve symmetrical designs. This may be seen in the highest and in the simplest forms of ancient architecture. When the parts of the design are prescribed, as in the representation of objects in nature, he soon tires of mere mechanical repetition of the same things in a given sequence, and strives to convey some ulterior idea by the manner of joining these parts. This gives life and language to sculpture and painting, and character to handwriting.

In the process of evolving a signature, which must be

again and again repeated from an early age till death, new ideas occur from time to time, are tried, modified, improved, and finally embodied in the design. The idea finally worked out may be merely a short method of writing the necessary sequence of characters, or it may present some novelty to the eye. Signatures consisting almost exclusively of straight up-and-down strokes, looking at a short distance like a row of needles with very light hair-lines to connect them: signatures begun at the beginning or the end and written without removing the pen from the paper: signatures which are entirely illegible and whose component parts convey only the mutilated rudiments of letters, are not uncommon. All such signatures strike the eye and arrest the attention, and thus accomplish the object of their authors. The French signature frequently runs upward from left to right, ending with a strong down flourish in the opposite direction. All these, even the most illegible examples, give evidence of experience in handling or mishandling the pen. The product of the hand which writes most frequently is often very much harder to decipher than the worst specimens of an untrained hand. The characteristics of the latter are usually an evident painstaking desire to imitate faulty ideals of the letters one after the other, without any attempt to attain a particular effect by the signature as a whole; and in very extreme cases the separate letters of the words constituting the signature are not even joined together.

But the simulation of such a signature by an expert

penman will usually leave enough traces of his ability in handling the pen to pierce his disguise. Even a short straight stroke into which he is likely to relapse involuntarily will bear witness against the reality of the clumsiness he feigns. It is nearly as difficult for a master of the pen to imitate an untrained hand as for the untrained hand to write like an expert penman. The difference between an untrained handwriting and the trembling effort of an experienced writer who is ill or feeble, is that in the former may be seen abundant instances of ill-directed strength, and in the latter equally abundant instances of well-conceived design with a failure of the power to execute it.

Observation of such points is frequently of value in aiding the expert to understand the phenomena which he meets. They belong to a class which does not require the application of standards of measure, but only experience and memory of other similar instances whose history is known, and a sound judgment to discern the significance of what is seen.

Only general suggestions like those above referred to can be given to guide the student of handwriting, but the differences between genuine and pretended states of the writer will generally become apparent with practice.

CHAPTER II.

THE WRITING INSTRUMENT.

Pens, Past and Present.—The age has been for two generations a steel-pen age. The greater number of forgeries have been accomplished by means of this instrument in deference to its all but universal adoption as the instrument of writing. It would be more exact to say that metal pens have superseded the old goose-quill, which latter is only found among the conservators of by-gone customs, along with shirt-frills and snuff-boxes.

Except that the old-fashioned article makes a "softer" pen (one with which less pressure is needed to induce a flow of ink), the principle involved is the same,—*i.e.*, a semi-cylinder to retain the supply of ink by its capillary attraction, fashioned to a point split in two, so that by pressure a measurably broad column of ink may be made to rest upon the paper, and by moving the pen the liquid is left behind as a line which marks its course. More pressure is required to separate the nibs of metal pens, but the force required is seldom great, and the choice of a stiff or a yielding pen is the result of the habit of the writer to employ little or much pressure. One difference, however, is to be noted,—namely, that whereas furrows are rarely made by quill-pen nibs, they

are, as a rule, easily observable under the microscope in writing which has been done by metal pens.

These furrows are often of importance in forming an idea of how the characters were traced, whether rapidly or slowly, with or without unusual tremor, etc., and in this respect metal pens (tipped with steel, gold, iridium, etc.) add a characteristic worthy of notice to the traces left by quill-pens. Again, in old times, when the trimming of a pen was constantly undertaken in the course of any long writing, the same document was liable to show differences of thickness and smoothness of lines, free or ink-filled loops in different parts, even when written by the same hand and at the same sitting.

With a metal pen such changes are less likely to occur, and consequently one element of possible confusion is avoided.

It is sometimes of interest to note the fact that different parts of a writing have been made with different kinds of pens, fine- and coarse-pointed, broad-nibbed, stiff or pliant; and such observations have more significance in a steel-pen than in a quill-pen age. But in late years the stylographic pen has been widely adopted, and threatens to invade all classes of writing, and to modify the methods of studying the tracings of the writing instrument in some degree. The principle of construction of these pens, known by various names, is that of a hollow holder to contain the ink, tapering to an acute hollow cone, the perforation being closed by a wire of platinum, tipped with iridosmine, or some other

extremely hard substance, to resist the abrasion of the paper, and held down so as to prevent the continuous flow of ink, either by a small leaden weight (the Mackinnon) or by a fine spiral spring (the stylograph).

The pressure of the point upon the paper pushes back the tapering wire and allows the ink to escape around it to the paper. The writing appears under the microscope as a central shallow furrow on the soft paper, usually narrower than the ink line which stains its edges for a greater or less distance from both margins. The nature of the instrument and its method of feeding the ink upon the paper destroy the possibility of shading, an ornamentation so important to the calligrapher, but it has compensating advantages in the facility it furnishes to write uniformly, rapidly, with a constant supply of the same ink, without blots, and without the necessity of pausing to replenish the pen. The main characteristics which can be made the subjects of exact measurement remain, and the stylograph has not rendered the practice of forgery notably easier.

CHAPTER III.

THE WRITING FLUID.

Inks usually met with.—The inks in common use over the United States at the present time, and for some years past, are not as numerous as one might be led to conclude. There are probably fifteen or at most twenty in all, including the most popular blue, red, magenta, and green inks. But among these there is a notable difference in character. Some are thick, heavy, and glossy in character, and flow sluggishly from the pen. Few of these become much darker by standing. In this class will be found the copying inks and those in which a large quantity of gums or similar thickening agents is used.

Other inks are pale, limpid, and flow easily from the pen, and this class usually shows a notable darkening by exposure to sunlight and air.

The most experienced judges prefer those writing fluids, of which the iron nutgall ink is the type, which grow gradually darker for two weeks or more after the writing is made. The proper black is only attained after the complete oxidation of the ferrous salt, which takes place on and in the paper, the final product becoming incorporated with the fibre. But since this ink is pale when first used, some permanent blue, like indigo or

alkali blue, is added to the fluid in order that the writing may be distinctly legible from the first.

It will be unnecessary here to refer more particularly to the intermediate varieties or to discuss their various compositions. The exhaustive treatise of Schluttig and Neumann [1] on this subject may be referred to for further information than is contained in the chapter of this book which discusses inks.

Judgment of Color, Lustre, and Shade.—The color or blackness of one ink as compared with another is very difficult to judge by the naked eye, or when a broad is compared with a fine line. In very numerous cases an examination of the two lines when magnified will lead to the reversal of a judgment based upon examinations by the naked eye alone.

In this kind of preliminary examination, which at first thought seems easy, it is better to have recourse to the magnifying glass or microscope, which presents a smaller area with great distinctness.

Differences in Color and Shade.—The judgment by the naked eye as to the colors or shades of two inks is very likely to be erroneous, partly because, when a lighter ink is more heavily massed than a darker one, the effect on the retina is as if it were the darker. Under

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[1] Die Eisengallustinten. Grundlagen zu ihrer Beurtheilung. Im Auftrage der Firma Aug. Leonhardi in Dresden, chemische Fabriken für Tinten, bearbeitet von deren Chemikern Oswald Schluttig und Dr. G. S. Neumann. Mit 2 Holzschnitten, einer schwarzen, und zwei farbigen Tafeln. Dresden: v. Zahn und Jaensch, 1890.

the magnifying glass the field is more restricted, the finer lines are broadened, and one has larger areas of ink to compare with less surface of strongly contrasted white paper. Similarly, an ink without noticeable bluish tinge to the naked eye may appear quite blue under the glass, where the films of ink are broadened and thinned and their characters better observed.

The methods for detecting these slight differences by prisms of colored glass will be mentioned later.

In order to judge whether two marks have been made by the same ink, they should be viewed by reflected light to note the color, lustre, and thickness of the ink film. Many inks blot or "run" on badly-sized paper,—*i.e.*, the lines are accompanied by a paler border which renders their edges less well defined.

Even on well-sized papers this class of inks usually exhibits only a stained line of no appreciable thickness where the fluid has touched the paper.

The copying and glossy inks, which often contain a considerable quantity of gum, do not "run" or blot even on partially-sized paper, and show under the glass a convexity on the surface of the line and an appreciable thickness of the film.

It does not always follow when an ink has made a blur on one part of the paper and not on another that the paper has been tampered with. A drop of water accidentally let fall on the blank page will frequently affect the sizing in that place: and, besides, all papers are not evenly sized in every part.

The inks rich in gum, or those concentrated by evaporation from standing in an open inkstand, give a more lustrous and thicker stroke. Some inks penetrate deeper into the pores of the paper than others, and some produce chemical effects upon the sizing and even upon the paper itself, so that the characters can easily be recognized on the under side of the sheet. In some old documents the ink has been known to so far destroy the fibre of the paper that a slight agitation of the sheet would shake out as dust much of the part which it covered, thus leaving an imperfect stencil of the original writing.

It should be remembered here that in the last twenty-five years, or since the introduction into general commerce of aniline colors, which Hofmann discovered in 1846, these latter have been employed more and more in writing fluids; not only in mixtures of which they are the principal ingredients, but to a greater or less degree in all inks. Their presence, even in small quantity, in the gallo-tannate of iron and logwood inks can generally be detected by an iridescent and semi-metallic lustre.

The presence of numerous blots and unduly thickened lines in writing will indicate a more than desirable flow of ink, which may result from its fluidity, or the clumsiness, or unnecessarily strong pressure of the writer, or all three. In certain cases this may furnish a clue to assist in determining whether two writings or parts of the same document have been written by the same hand or with the same ink.

CHAPTER IV.

THE SUBSTANCE WRITTEN UPON.

Materials of which it is made. — The material which bears the writing under investigation may be of cotton, linen, esparto, wood pulp, or parchment. All but the last have readily recognizable fibres, each differing in appearance and in fact from the other. Photomicrographs of these may be seen in the "Text-Book of Paper Making,"[1] by C. T. Cross and E. J. Bevan, and in other similar treatises and articles.

Paper Making. — The fibres are interlocked with each other during the process of "beating" the pulp, and are further "loaded" with clay, kaolin, or an asbestos-like material called "agalite," which is nearly pure magnesium silicate. These materials, which are added to all but special grades of paper, are not harmful constituents unless in excessive amount, and the last named being by nature fibrous, like the organic materials with which it is mixed, assists in binding them together, and imparts a hard finish to the paper. The "pearl hardening" is effected by means of precipitated calcium sulphate (gypsum, plaster of Paris).

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[1] E. & F. N. Spon, 125 Strand, London, and 35 Murray Street, New York, 1888.

In addition to these "loading" ingredients, papers intended to be written upon are "sized" or immersed in an aluminum resinate soap mixed with about one-third its weight of starch paste, which serves to hold together the fibres and also to prevent the ink from running. After about four parts by weight of this mixture to one hundred parts of the pulp have been thoroughly mixed, a solution of alum is run in, after having been dissolved in lead or copper tanks, as this substance acts rapidly on iron, and would saturate the pulp with the iron salt, and thus impair its value. It may be said that, in spite of the careful preparation of the paper pulp, the finished product is often adulterated by iron in some slight degree and will give a reaction for that metal by a sufficiently delicate test. Nearly three times the amount of alum is required to precipitate the resin from its combination with sodium. Ultramarine blues and aniline pinks are added to counteract the yellowish color of the cellulose. Hand-made papers are sized by dipping them into a solution of gelatin and hanging them up on lines or poles to dry. The sheets are then calendered, either by passing them between heated or cold metallic rolls, or between one of metal and one of compressed paper; or by pressing them in larger bundles of alternating paper and metal plates (*Cross and Bevan*). The effect of this is to give the surface of the paper a hard and often polished surface, on which the tracing of ink remains without running or blotting, is absorbed into the loading and size, and also stains the

fibres of paper of which these materials fill the interstices.

Erasures.—When an erasure is made on the surface of such a paper, the mineral and organic materials of the sizing and loading are removed, and the fibres of the paper which they unite are deranged in form and position. Such a surface exhibits invariably the "teezed-up" ends of the fibres, and generally shows by the agreement in their direction in what way the scratching was done.

Even in cases where a substitute for the sizing has been so successfully added that no change in color or surface is observable, the fibres will show by their unusual positions that they have been disturbed. When an attempt has been made to write over the place without sufficiently restoring the sizing, the effects can be seen in the running of the ink between the fibres and the staining of the body of the paper to a considerable depth from the surface and to a considerable distance from the spot.

Insertion of Pages.—In cases where a document of several pages is under investigation, and tampering is suspected with only one or two of the sheets, a general investigation of the character of the paper, as well as of the ink in each sheet, becomes necessary. If the paper be ruled, careful measurements of the distance apart of the lines in each sheet and the distances of the first and last lines from the upper and lower edges of the paper should be made and compared.

Water-marks.—Any water-mark or other device wrought into the paper should be looked for. The

water-mark is made by receiving the soft pulp on a wire screen on which a design of some kind is placed. When this pulp is raised out of the tub, there is less pulp over the raised design (or more if the design be in relief) than in the rest of the sheet, and although the subsequent pressure to which the paper is subjected prevents the eye from detecting the difference in thickness, the design remains.

Other marks are introduced by the "dandy roll," a light roll covered with raised wires in the form desired, pressing lightly on the paper while still moist, while the other side has the mark of the wire cloth. If the "dandy roll" be also covered with wire cloth, the two sides appear alike, and the paper is called "wove" (*Cross and Bevan*).

Any such marks in the paper furnish excellent means of establishing whether or not one or more of the sheets of the document have been substituted. When the water-mark is faint, or not immediately noticeable while using the paper, it is so much the better as a means of identification.

Concealment of Telltale Spots.—Awkward marks which might prove telltales are sometimes scribbled over with a pen, or covered by a seal, or in by-gone days, when wafers were commonly used to close letters, one of them was affixed to the paper. Chevallier and Lassaigne have met with a case where pieces of paper were pasted over the suspicious place.

A patient and systematic study of the paper will

usually lead to a suspicion of such treatment, and will suggest means for its discovery.

Parchments.—It sometimes happens that the document is a veritable parchment. Parchments are usually made of the skin of sheep or lambs, if intended for writing purposes. Goat and wolf skins used to be employed for drum-heads (*Peignot*).

The finer and smoother sorts of parchment called vellum are made from the skins of very young calves.

The preparation of the skin for writing purposes has scarcely been improved since the time when Hildebert, Archbishop of Tours (born 1054), thus partially described it in a sermon. He says, " A writer first cleanses his parchment from the grease, and takes off most of the dirt. He then entirely rubs off the hair and fibres with pumice stone. If he did not do so the letters upon it would not be good, nor would they last long. He then rules lines that the writing may be straight," etc.

Practically when the skin has been deprived of its hair or wool it is placed for a time in a lime pit, whence it is taken and stretched on a frame and drawn tight.

The workman then scrapes the flesh side with a blunt iron instrument, wets it with a moistened rag covered with powdered chalk, and rubs it with pumice stone. This operation is repeated once or twice, when the hair side is turned and scraped. After drying, it is again scraped with a finer tool.

The parchments of the time of the Romans must have

been very superior to those of the early middle ages, and these again to the parchments of the eleventh and twelfth centuries. From that time to the sixteenth century, when paper began to be employed, parchment gradually became an article of luxury and imperfect manufacture. It is still occasionally used on account of its great durability.

In examining a parchment on which a supposed forgery is inscribed, Mr. Sittl remarks that a similarity between the two sides of the sheet (which can be determined by the equal visibility of the ink) gives very strong reason to doubt the great age of the skin, because there is always a marked difference between the hair side and the flesh side in really old parchments. The great differences of inks of different periods facilitate the discovery of the fraudulent character of corrections, emendations, and notes. These observations, however, apply to cases where it is desired to judge parchment documents belonging to centuries long past.

Erasures in parchments produce prominences on the opposite side of the sheet. The ink placed upon such erasures has a peculiar bluish tinge. It happens at times that a whole page is taken out, either by scratching or rubbing with pumice (which was the practice in the eleventh century, when parchment became so valuable that it was common to keep up the supply by erasing the writing on old parchments) or by washing.

Where the latter method was used the writing, as in palimpsests, can be made to reappear by warming.

The parchment can either be laid on a hot plate or pressed with a hot flat-iron between two sheets of paper (*Sittl*).

Furrows traced by the Pen-nibs.—Under the microscope the furrows traced by the pen-nibs are usually easily visible, and they differ with every variety of pen employed. A stiff, fine-pointed pen makes two comparatively deep lines a short distance apart, which appear blacker in the writing than the space between them, because they fill with ink, which afterwards dries, and produces a thicker layer of black sediment than elsewhere. The variations of pressure upon the pen can easily be noticed by the alternate widening and narrowing of the band between these two furrows. The tracing appears knotty and uneven when made by an untrained hand, while it appears uniformly thin, and generally tremulous or in zigzags, when made by a weak but trained hand. (As will be seen further on, both of these characteristics appear even in the best handwriting under high magnification.) A soft and broad-nibbed pen exhibits the same peculiarities, with the difference that there are no fine lines, but broad and broader lines, not infrequently interrupted by blots, and obliterations of letters by the untrained hand.

The depression of both borders of a pen-stroke gives rise to the appearance of convexity in the line which is observed under the microscope and in photomicrographs of lines. This furnishes another means of discriminating between genuine and spurious writing; but, owing to

the fact that the differences in depth of the furrows are very slight, even with notable differences of pressure, it is not a guide upon which the investigator can always rely. Still, within certain limitations it is an important object to study, and may give indications of value to corroborate or refute the hypotheses based upon other lines of study.

Stylographic Pens.—As was remarked before, the introduction of the stylographic pen has changed the character of the letters when viewed under the microscope, and in the future, when instruments executed by this writing tool shall come under examination, some of the clues which were useful in the metal-pen era will disappear.

The stylus, or light metal wire, which acts as a plug to restrain the flow of ink when the pen is not in actual use, is kept down either by a very small weight, as in the Mackinnon pen, or by a fine spring, as in the ordinary stylograph. The amount of pressure necessary to press this needle back is so slight that the weakest hand is capable of accomplishing it, and as there is practically no furrow observable, and the ink flows over all sides of the stylus to the paper, the effect is of writing with a very fine camel's-hair pencil. Furrows and convexity are replaced by concavity, and shading in the line disappears. Even the effects of tremor are not so easily discernible, when visible at all, whether heavy or light pressure be employed, because the point of the cone smears away all minor deviations. The arrest of the pen on the

paper does not produce a notably heavier deposit of ink, because the friction on all sides of the annular space in the nozzle is sufficient to stop the flow until the pen is again put in motion (provided that the latter be in good order).

CHAPTER V.

PRELIMINARY EXAMINATION.

Care of the Document.—At the very outset of an examination, the greatest care should be taken to guard the document which is to be its subject from handling and soiling, and especially to protect it from finger and other marks on the written characters. A suspected document is generally not in first-class condition when it comes to the expert, because expectant litigants who have scanned it, and it must be said, also some learned attorneys who ought to know better, are singularly careless about their treatment of an object upon which the fate of the litigation may turn. It is not unusual to find on the pages of contested papers foreign pen-marks (!) which could be traced to the careless handling by attorneys or their clerks of pens moistened with ink.

Usually it is the litigant who suspects that there is something fraudulent in the document, and by way of satisfying himself on the subject thumbs it or pricks it with pins, with as little regard for the consequences as if the delicate points to be investigated could not be

obscured. If it be the counsel who first decides to subject the document to expert examination, it may fare little better. It would seem that a specific amount of rough handling and of extraneous matter deposited must pave the way to the conviction that the paper should be an object of scrutiny. As if the thumbing and pulling were not enough, it is usual for the keeper of the document to fold and refold the paper each time it is taken from its repository.

It is very strange that gentlemen who, more than all others, should know the value of keeping documents in their original state, and whose daily experience teaches them that continually refolding a paper tends to wear, tear, and destroy it, should persist in this practice. A document which bears upon it the evidence which may convict a malefactor of forgery, or which may decide the ownership of a fortune, should be carefully and tenderly handled. It should be laid between sheets of clean white paper without folding, unless its size be so great as to render this very difficult, in which case it should be folded but once, and, if possible, in other than the original lines, and invariably so that the folds do not cross any important part of the paper. It is usually practicable to fold the document without crossing any lines; but when this is not the case, those parts of the instrument should be chosen which are least material to the investigation, no matter what sort of a form this leaves it in. In most cases the document can easily be laid out flat, covered with two pieces of clean writing-

or wrapping-paper, and carried in a large envelope or portfolio. It is much better even to roll it lightly in its covering papers than to fold it after it has once been taken up for study.

Least of all should any object capable of imparting a color to the paper be brought near the part or parts of the document about which suspicion exists. In the interest of justice this should be as sacredly guarded as a ballot-box, for upon the testimony which it gives important questions may depend.

When the microscope is to be used to examine parts of the writing, it is sometimes necessary to fold the document in order to bring the part to be scrutinized under the lens without interference from the stand of the microscope, which will usually afford a space of seven or eight centimeters between the brass upright and the axis of the lens.[1]

In this case it is better to make new folds, and to steady the document on a plate of clean glass or metal of about five centimeters on a side, for it is usually convenient to remove the ordinary table for microscope-slides.

A photograph, if possible of natural scale, should

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[1] The necessity for this has been obviated for powers up to one hundred and fifty diameters by a simple and convenient contrivance of Mr. Hagan, whereby a stand without stage carries the microscope. The document is laid flat on the table and covered by a sheet of plate glass on which the instrument slides on cork shoes to prevent scratching.

always be taken before the investigation begins, either of the whole or of the important part of the document, and none but chemists, experienced in testing important papers, should be permitted to apply reagents to them.

First Scrutiny.—It is a very useful preliminary to any physical investigation to look at the document carefully, reading its lines, and thus familiarizing one's self with the style of expression, as well as the character of the writing expressed in the letters, the groups of letters, the spaces between words, and the placing of sentences. By doing this, and without any conscious effort, a certain general effect due to the writer's habit in dealing with these elements of individuality will become impressed upon the observer. It is in this way that connoisseurs judge of the authorship of paintings or statues, and are enabled to distinguish copies and even replicas from originals.

In every case the investigator should endeavor to imagine himself in the position of the bona fide writer whose supposed work he is studying, and to reproduce his impressions, such as that of not having space enough to finish a word which has caused the original writer to crowd his letters together unnaturally, etc., etc.; in short, to confront himself with the problem (whatever it be) which the face of the document pretends the writer has solved by the means which have aroused suspicion, such as the alteration of a figure, the interpolation of a word, or complete interlineation, etc.

When sufficient time has been taken to get all the

light to be derived after attaining this frame of mind, the next step can be taken.

Scanning by Transmitted Light.[1]—It is never amiss to look at the document placed between the observer and a strong daylight,—not often direct sunlight. A northern exposure is a very favorable light in this hemisphere for these studies as well as those of art. Transmitted light often tells tales on a forger, sometimes revealing erasures by the area over which a stronger light reaches the eye; sometimes by a water-mark which is inconsistent with the supposed date of the paper.

Sittl, of Munich, an expert on handwriting, relates an instance of a document bearing the date of 1868, which was written on paper with a water-mark representing the eagle of the German empire, which, as all the world knows, was not employed until after the French war, in 1870.

Remains of Tracings.—It sometimes occurs that the forger, fearful that his attempt to imitate another's writing would be too easily detected if made with a free hand, sketches in pencil the characters he intends to make in ink on the document, or traces them by means

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[1] For this purpose, as well as for tracing, the writer has found it convenient to use a box, of which the top is made of a sheet of glass, and the lower half of one side is open to admit sunlight upon a mirror inclined to 45°, which throws the rays directly upward and through the paper to be examined.

of blackened paper at the appropriate place.[1] The evidences of this are very likely to appear when the document is examined in transmitted light.

General Style of the Document as a Whole.— When an entire document or page is forged, the ornamentation, flourishes, or capitals at its head will often be seen to be out of keeping, either with its nature or with the supposed author's habits in similar cases. As observed by Mr. Sittl, in a writing all must agree: place, day, year, handwriting, superscription or heading, signature, and material carrying the writing, especially paper, both as to constitution and color, and ink.[2]

Other observations indicated above having been made, the free or cramped character of a signature or a word is often of importance in the preliminary examination about to be described. It happens not infrequently that the desire to get a given number of words into a definite space leads to an entirely unusual and foreign style of writing, in which the accustomed characteristics are so obscured or changed that only the systematic analysis to be detailed farther on can detect them. If there be no apparent reason for this appearance in lack of space, the

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[1] In one case which occurred in the writer's experience a clerk possessed himself of a rubber autograph stamp of the person whose name he forged, and produced a light facsimile of the writing on the paper by means of carbon paper.

[2] Illustrirtes Lexikon der Verfälschungen, etc. . . . Herausgegeben von Dr. Otto Dammer, Leipzig. J. J. Weber, 1887. Article "Handschriften."

cause may be the physical state of the writer or an attempt at simulation. If a sufficient number of genuine signatures are available, it can generally be determined which of these two explanations is the right one.

Selection of a Method of Procedure.—A basis can usually be laid for the choice of a line of investigation by a careful study of the writing or writings by the unaided eye. It is to the unaided eye that these writings have been addressed, and to the unaided eye they tell their story, either simple and straightforward, or hesitating and suspicious, or labored and doubtful. The latter class of cases presents the greatest difficulties, for it is not always proof of spuriousness that the writing has been painfully and slowly produced. There are minds so easily impressed with a sense of responsibility, that the writing or signing of any paper important in its bearing on the writer or his property will cause him to disguise his hand to some extent involuntarily, as many persons disguise their features involuntarily when being photographed. It is not at all easy to distinguish by the naked eye alone between this form of disguise and a forgery, but it will generally be found possible to do so by the application of the methods described elsewhere.

Nevertheless, the contemplation of the writing or writings under investigation will generally result in putting one in possession of the general character of the hand, and will aid the after-study when it appears

through more minute analysis what causes the characteristic features.

An hour may usually profitably be spent in merely scanning each letter of a document, and the writing by lines, paragraphs, and pages before a closer scrutiny. Gradually, if the writing be genuine, its character will begin to reveal itself, and unconsciously an hypothesis as to the physical causes of the irregularities or characteristics will be formed. When this preliminary glance is concluded, some course will suggest itself for the next step. If it be a question of the genuineness of a single signature, and thirty or forty undisputed signatures (the more the better) are at hand, the most universally applicable method to employ is that of a careful measurement of the sizes, distances apart, etc., of the letters and of their angles. This will be made the subject of a separate chapter.

Choice of a Magnifier.—Although a great deal can be determined in a general way by close observation with the naked eye, it is always best to employ some magnifying power; usually an ordinary hand lens or pocket magnifier will suffice, but the writer has found it better to use a microscope objective of low power (four or five diameters), which is provided with an easily-slipping sleeve, terminating in a diaphragm which cuts out the light entering the outside rim of the lens. This sleeve may be pushed out for one or two centimetres, and the particular spot under examination isolated from the adjacent parts without undue magnifi-

cation. It is one of the popular fallacies that a high magnifying power is desirable in all cases of difficulty, but the reverse is usually the case in the general examination of handwriting.

The best authorities prescribe a magnifying power of not more than ten diameters (*Hager and Holdermann: Untersuchungen*) for ordinary observations.

Restricted Use of Higher Powers.—For special purposes higher powers are often useful, but it is seldom that magnification of more than one hundred and thirty diameters is required.

An ocular examination of the ink in the various parts of a written instrument will generally suggest whether or not it is probably the same, and an ordinary magnifying glass of low power will render more service in detecting the predominant color than high powers of the compound microscope.

CHAPTER VI.

THE SEQUENCE IN CROSSED LINES.[1]

Importance of the Determination.—It often becomes important to determine which of two crossed ink lines was written first. Many cases of forgery depend upon

[1] Chemical methods for the determination of sequence in crossed lines will be found in the part of this book dealing with chemical questions.

the answer to this question, which therefore is one of more than ordinary importance.

As a rule, when the underlying line has been drawn with a heavy black ink, and the overlying line with a lighter one, no direct observation in the usual way will suffice to determine their sequence with certainty.

Superposition.—Where two lines cross, and the upper and lower cannot be distinguished by perpendicular vision in the microscope, their order of superposition may occasionally be judged by the traces of flow from the sides of the later stroke in both directions from the pen along the edges of the line previously written; and sometimes by two continuous black lines corresponding to the paths of the two nibs tracing the upper line. These appearances are often observable only through the microscope. The cause of the first may be the greater capillary attraction of the particles of the ink film first deposited than of the particles of the clean paper surface for the particles of the fluid ink; and of the second the larger quantities of ink deposited in the deeper furrows of the most recent mark.

Whether or not these be the principal causes, the fact remains, and a careful scrutiny of the edges of crossed lines at their point of contact will often reveal which was the last to be traced.

As has been already mentioned, another phenomenon sometimes observable under the microscope, which may lead to the same result, is the staining or coloring of the loose fibres overlying the first line, or of those adjacent

to it, which may have escaped being colored by the first ink; or the dulling of the lustre of the inferior ink if the superior be less lustrous; or the contrary effect in the opposite case.

It may happen that in retouching a written document for purposes of fraud the writing fluid last used is indistinguishable from the first in color and lustre, but may differ in the number or the size of its solid suspended particles or in some other characteristic.

In such a case the microscope can be made effective in determining the degree of uniformity which appears in the ink lines. However skilfully additions to the text may have been made they are not likely to elude this test, because the chances are very great against even the ink from a given bottle remaining constant for any considerable time in all the characteristics observable in the microscope.

Ink Lines Transparent.—Ink films which appear to the eye as black opaque lines in contrast with the lighter substance on which they are written are not so in fact, but, on the contrary, extremely translucent and even transparent, as an observation of an ink line made with a pen upon a piece of plain glass will show. Where the line is fine, as in ordinary writing, the obstruction which such a film would offer to seeing objects through it is much smaller than is generally supposed.

If a drop of the heaviest black ink be placed upon a plain glass microscope-slide, and a cover glass or another slide be placed over it, with slight pressure the film will

become as thin as it is after drying on ordinary paper. It will impart some color to the objects viewed through it, but it will not entirely obscure even very light lines or points on paper below it. (See Plate III., Fig. 7.)

This being the case, we should regard two crossed lines as transparent films like two strips of lightly-colored glass crossing each other. The light which falls at the point of intersection penetrates to the paper below, and is reflected to the eye, twice traversing the ink lines and emerging with a loss by absorption equal to twice their combined absorptive power. That light which strikes but one of the lines loses in its double passage through the film only so much of its rays as that one ink with twice the thickness in which it appears is capable of absorbing. Consequently the absorption at the point of intersection of the limbs of the cross will be greater and the color darker than on either of the two branches which make the cross. Each of the films is usually so thin that it is impossible to observe any stereoscopic effect when the direction of light is perpendicular to the plane of the paper. Two phenomena, however, may sometimes be observed in this way, which bear upon the question of superposition.

Widening of the Upper Line.—The overlying line is likely to show a widening which is masked at the small area of their intersection for the reason just given, —namely, because their respective effects upon light over this little square are so blended that they cannot be separately distinguished by the eye; but if the colors or

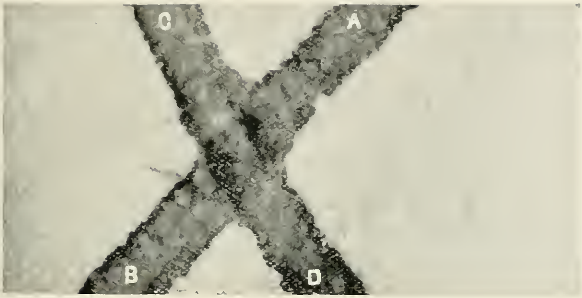
shades are sufficiently different to enable the eye to distinguish one ink from the other (as is likely to be the case if any considerable period of time have elapsed between the tracing of the two lines), the line of the upper ink will often be seen to broaden just before it traverses the lower, and to narrow on leaving it. See Plate I., Fig. 1, which is a photograph of a cross made with red ink and magnified twenty-four diameters. The line *c d* was drawn over *a b* while the latter was wet. Observe the broadening of the descending line *c d* at the first and its narrowing at the last contact with *a b*. If the two fluids are indistinguishable in color, lustre, or shade, etc., this method will fail, unless some conclusion can be drawn as to the line to which the broadened and again narrowed parts belong. The broadening effect due to capillarity will be greater when the lower line is still wet than when it is dry.

Plate I., Fig. 2, represents a twelvefold linear enlargement of a part of a letter in a signature. The straight line passes over the curved line. The broadening of the straight upper line as it crosses the curved line from left to right, and its narrowing on leaving it, are perhaps due to the passage of the ink line into and out of the sphere of capillary attraction of the still moist underlying line. Plate I., Fig. 3, represents the same object magnified thirty-five diameters.

Staining of Straggling Fibres.—The other observation also applies to those cases where there is a visible difference in the appearance of the two inks which causes

PLATE I.

FIG. 1.

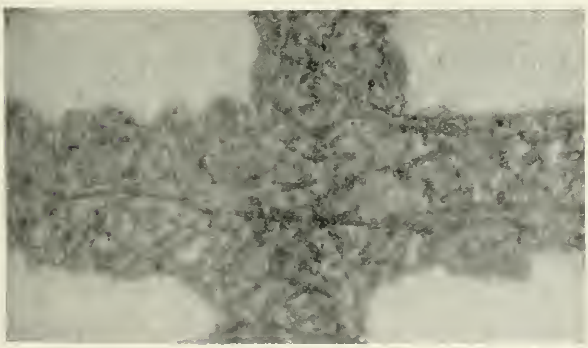


Cross in red ink, magnified twenty-four diameters.

FIG. 2.

Cross in a signature, magnified twelve diameters.

FIG. 3.



Cross of same signature, magnified thirty-five diameters.

the overlying ink to impart its color, or lustre, or other appreciable peculiarity to the lower ink at their place of crossing.

Often when a more glossy ink underlies, this appearance will be nothing more than a slight dulling of the lustre ; or if the overlying ink have a peculiar color a few straggling fibres may be noticed on the upper surface of the place of junction which show traces of this color. If there be no such differences between the inks this method also is inapplicable.

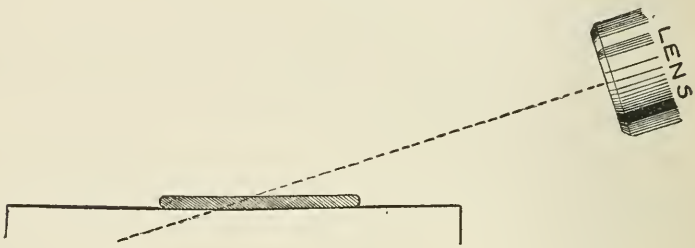
Method by Oblique Vision.—A third method employed by the writer has been more successful. It is by viewing the crossed lines obliquely.

If two strips of differently-shaded glass be crossed, the edges of the square formed by their junction bound with black tape (to conceal as far as possible which strip is uppermost), and the whole backed by white paper and held several feet from the observer in a strong light coming from his direction, the central square of their junction will appear darker than either of the strips, and it will not be easy to determine which of the two is uppermost. If now this cross, with its paper, be gradually inclined to the horizon, less and less of the rays which strike its surface will twice traverse both plates at their junction before reaching the eye, and the number of rays which penetrate only the upper strip and reach the eye will be continually greater at each successive degree of inclination.

When the angle is such that a large majority of the rays which reach the eye penetrate only the upper strip,

the overlying strip at the point of intersection will be seen to correspond in color and other characteristics with two of the arms of the cross, and to differ from the other two. The uppermost strip will appear to be (as it is in reality) a continuous line, either lighter or darker than the other, from the extremity of one arm across the intersection to the opposite extremity. The underlying strip will seem to be cut in two, and its peculiarities of

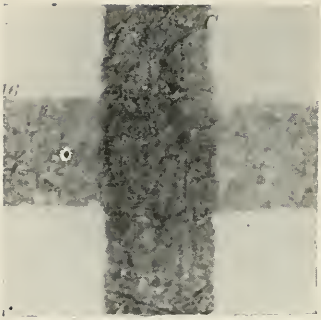
Fig. 6.



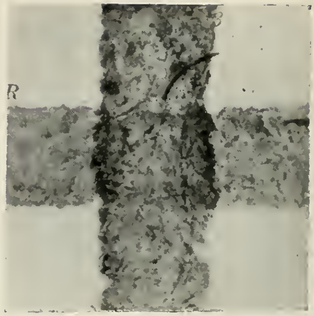
color, lustre, structure, etc., will only appear in the two opposite arms, divided by a small area at the intersection with the other line, which does not match them.

Applying this principle to the crossing of lines of ink on a paper: if a lens of small magnifying power be so placed that the axis of vision be inclined at an acute angle to the plane of the paper, and directed to the point of intersection of the lines, the illumination as before being oblique; one of the two, whether it be the lighter or the darker, will be seen to make one continuous limb of the cross alike in color and shade from end to end. This is the upper line.

PLATE II.



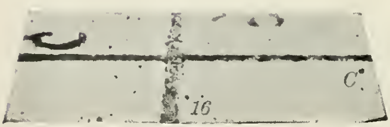
A



B

A 1

B 1



A 2

B 2

A, Cross made with the darkest and lightest (uppermost) of commercial inks.

B, Cross made with the same inks, the darkest uppermost. Plane of each cross perpendicular to axis of lens. Magnification, 20 diameters.

A 1, Cross of lightest and darkest inks photographed in plane oblique to axis of lens. The lightest ink on top and perpendicular to axis.

A 2, Cross of lightest and darkest inks photographed in plane oblique to axis of lens. The lightest ink on top and in vertical plane including axis.

B 1, Cross of lightest and darkest inks photographed in plane oblique to axis of lens. The darkest ink on top and perpendicular to axis.

B 2, Cross of lightest and darkest inks photographed in plane oblique to axis of lens. The darkest ink on top and in vertical plane including axis.

In all the above diagrams the darkest ink is designated by *3* when uppermost, and *C* when underneath; the lightest ink by *16* when uppermost, and by *R* when underneath. The magnification is four diameters.

Plate II., Figs. A, A1, A2, B, B1, B2, represent photomicrographs of intersections of the lightest and the darkest of commercial inks. The darker is designated by *C* when it is underneath and by *3* when it is above; the lighter is designated by *R* when it is underneath and by *16* when it is the upper line. Each is given once in an inferior and once in a superior position viewed perpendicularly, and twice in each situation viewed obliquely. The deeper color of the darker ink makes it appear to be the superior line in both cases when the axis of the photographic instrument is perpendicular to the plane of the paper. But when these same slides are photographed with the axis of the instrument oblique to the plane of the paper, the true order of superposition becomes apparent to the eye in the print. See A1, A2, B1, B2. The No. *16* ink, although much lighter in color than the other, is distinctly seen to pass continuously across the darker ink in an uninterrupted line in A1 and A2.

It will be understood by those familiar with microscope photography that if the plane of an object be ever so slightly oblique to the axis of the instrument, only a very minute area adjoining the axis of rotation will be approximately in focus, and in all positions, except where the plane of the slide is perpendicular to the axis of the microscope objective, the front and rear portions of this plane will be out of focus.

This gives to the ink line perpendicular to the axis of rotation less intensity than it really has, and might lead

some persons to suppose that, owing to this fact alone, the lighter ink maintains its character across the darker. It should be remembered, however, that the portion of the darker line which is crossed by the lighter is equally with the latter in focus. This area of crossing is not a mathematical point, but a space of sensible magnitude rendered easily visible by the magnification employed. If the darker line were really superposed, therefore, it would appear to be the darker in all positions and under any illumination, as can be seen in Figs. B1 and B2.

Figs. A2 and B1 are represented in order to show that the appearance is the same when the underlying line is made to coincide with the axis of rotation of the slide. In Fig. A2 the same slide was photographed as in A1, but the overlying ink, *16*, instead of crossing the field from left to right runs from top to bottom; yet although by this position the extremities of this line are out of focus, it is clearly seen to overlie the line *C*.

In the figure B2 the overlying ink, No. *3*, is as distinctly above the line R while in a horizontal position as it is in B1 while in a position perpendicular to the first.

A2 and B2 were prepared to meet a possible objection that either ink may be made to appear the upper or the lower in a phototype reproduction according to the manner of its presentation. This is true of the lighter of the two inks, but not of the darker. No change in the conditions of making the picture could make ink No. *3*

appear to be the lower in the three figures B, B1, and B2.[1]

The phenomenon is much easier to observe in the microscope than to represent in a photograph or a phototype print made from one, for the reason that the "glare" or lustre from the surface of the paper interferes with the definition of the ink lines.

For ordinary purposes the compound microscope, consisting of an eye-piece as well as an objective lens, is not necessary, and the test is more easily made with such a long focus and low power objective as was alluded to on a previous page.

If, for instance, a one-and-a-half-inch objective with a tubular diaphragm be laid almost parallel with the paper, and the latter held towards a good but not too strong sky-light, the actual succession of two crossed lines will be observable with greater facility than in a compound microscope.

CHAPTER VII.

HESITATION AND TREMOR OF FEEBLENESS, ILLITERACY, OR FRAUD.

Labored Writing.—It is not always an evidence of fraudulent intent that the writing shows evidences of slow and labored motion of the pen, but in connection with other facts this becomes an important point to ob-

[1] See Appendix, p. 249.

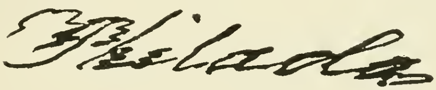
serve. It has been stated under the head of general observations of a writing that the hesitation and tremor, as shown by an illiterate person, by a feeble person or one under some condition of mental aberration, and by a well-skilled penman anxious to deceive, are all different. The pen-strokes of the illiterate person are strong enough, but uneven and erratic. No strokes nor parts of strokes are symmetrical. The handwriting is unformed and child-like, but not lacking in vigor. The pauses are made because of the inability of the writer to continue a line to its required length by a proper accommodation of the muscles, or to avoid an accidental obstacle, such as a grain of hard pulp or a crease in the paper, without making the pen sputter, or taking a new position with the hand. The attempt to imitate a copy or ideal in tracing a word or signature is similar to an attempt by the same hand to copy a landscape or to improvise one. Undue force is usually apparent everywhere, except on the hair-lines, where the attempt to be gentle necessitates drawing them slowly, and therefore in uncertain wavy lines. Parts of letters are drawn out of shape, and other parts written over them, as if the writer had memorized a certain number of strokes which it was necessary to make, and made them consecutively without regard to where his pen might be at the time he began each. In this respect it resembles the writing in the dark of a man whose faculties are dulled by fatigue or drugs.

Feebleness.—The signature or other writing of a not inexperienced penman, who is ill or feeble, is character-

ized by a general lightness of stroke and much tremulousness. If any parts of the lines are heavy, these parts are short, and not infrequently terminate with a perforation of the paper.

The pressure of the fingers is light, and when it is attempted to make parts of the writing heavier, too much weight is laid upon the pen without the ability to accurately gauge the amount of the added pressure, with the frequent result of puncturing of the paper. No line of any considerable length is free from the wavy evi-

FIG. 7.



Tremor of Feebleness.

dences of tremor, yet there is a distinct resemblance to the same word written in a state of health.

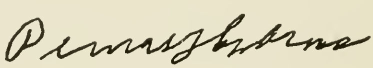
In the example given of the tremor due to feebleness (the word "Philada") it is clearly manifest not only that the idea of form which the writer had in his mind was excellent, but that in the main it was well carried out. The mean of all the divergences and waved lines makes a well-formed and symmetrical word. It must be confessed that the persistence in flourishes which bring into prominence the writer's weakness, and the correct general direction in forming the letters, are unusual, but the same features may be observed in lesser degree in any writing of a good penman which is tremulous on account of his feebleness.

All the points noted as characteristic of this kind of imperfect writing are strongly accentuated in this example. The writer was a gentleman of over ninety years.

Illiteracy.—In the case just mentioned there is a manifest attempt to reproduce a reasonable ideal which is partially successful, whereas in the illiterate signature the attempt seems to be to repeat a certain number of up-and-down strokes and their connecting strokes without considering what they were intended to produce as a whole. An identification of the signature of a very illiterate person becomes almost purely an identification of separate lines or letters, from the absence of any model of the signature as a whole in the writer's mind.

The example of the tremor due to illiteracy is given in the word "Pennsylvania." It was obtained from an ignorant carter, who, however, was not illiterate enough to produce so good a type as the preceding. The tremors and angular features observable are by no means indicative of lack of power, but the power is misdirected. After getting so far as the name of the

Fig. 8.



Tremor of Illiteracy.

great founder of the Commonwealth, the real difficulties begin, and in the struggle to master them the combat is transferred far from the guide-line of the paper. The last three syllables are little else than a repetition of the

prescribed number of strokes up and down, but the second part of the "n" has been carried over to the "i" and has made an "n" of that letter, so that the word appears to be "Pennsylzoina."

It is instructive to compare these two examples of tremor with each other.

Fraud.—The simulated tremor of a skilful penman is rarely successful in deceiving a trained eye aided by a moderate magnification of the writing.

The tendency to produce symmetrical tracings and natural curves is a second nature which cannot readily be overcome. Under the microscope, the rhythmic lapses from easy to perturbed writing and back again remind one of the imitation of a drunken man in amateur theatricals. The things which are really difficult for an illiterate or feeble person to do, such as the proper union of the small letters, are performed usually with address, as if the writer were in a hurry to commence acting his part in the next following letter. The dash (if there be one) will assume a graceful curve. The dot will appear in the place where the forger is accustomed to write it, or if both of these be carefully imitated there is sure to be some betrayal in the crossing of the "t's," the shading of some of the letters, the preservation of a straight line for the base line, or in some other part of the writing.

The signature of Isaac Taylor, represented on page 72, will serve as an illustration of the tremor almost inseparable from forgery.

A comparison of this signature and those of George W. Hawley and Enos V. Garrett (Fig. 11), with the composites of the names they were intended to simulate (Plate XIII.), will illustrate the fundamental differences

Fig. 9.

Tremor of Fraud.

of their characters and also the difficulty experienced by a good penman in feigning to be a bad one. The real signature of Isaac Taylor is not only tremulous from age, but is angular, unsymmetrical, and lacking in proper curves or proper straight lines. The above forged signature, on the contrary, is full of evidences that the hand which traced it was accustomed to make both with unusual skill. Observe, for instance, the general accuracy of the slope of the down stroke in the initial *T*, *l*, and first part of the *y*.

In these and similar instances used in the book as illustrations, for special reasons the tables of measurements to be explained later have not been printed. It will be apparent that such tables would show the same discrepancies which have been fully set forth in these pages where the names have not been given. One purpose of these illustrations is to show that the method of study by composite photography is valuable in getting at essential character and in detecting fraud.

The tremors of a simulating hand are rarely so numerous or so fine as real tremors.

Observations will be referred to farther on which demonstrate that in a single long stroke, like that of an "*f*" or an "*l*," there are usually many right and left deviations from the straight line which the ordinary penman in a normal state of health attempts to trace; and while it is not possible that these should exactly overlap in any two signatures, nor probable that they are invariably identical in number, yet in both respects two such lines by the same hand are apt to resemble each other more closely than any such line by another hand will resemble either of them. This tremor is natural to all handwritings, and is what prevents the most practised hand from drawing a perfect straight or curved line, though its effects are not easily visible except by the use of magnifiers. The faltering due to age or feebleness is greater in the extent of the excursions of the pen; but, besides these deviations, more numerous and finer tremors are superposed in all writings.

So fine are these, indeed, that they cannot be simulated, and the tremors, even were it possible to produce them artificially, would not resemble those they were intended to imitate.

This being so, one of the best means of detecting the fraudulent character of a writing purporting to be by a feeble person is the comparison of the tremors of both kinds evidenced in his genuine writing with those in the suspected imitation.

Retouching.—The repainting or retouching of a letter or part of a letter is not always evidence of fraud. Many persons contract the bad habit of going over what they have written with a pen to correct blemishes, and this habit sometimes becomes so pronounced that the writer invariably repaints his signature, whether it show blemishes or not. To a person in the habit of retouching his own writing an unconscious skill is ultimately developed which enables him to put his pen more nearly than another at the exact point required, and to join two disconnected lines with an accuracy far in excess of anything else of the same kind which he is capable of accomplishing. It is not rare to discover the habit only after a minute examination of numerous specimens of the writing under considerable magnification.

No hand is capable of tracing a line of any great length on paper without leaving abundant traces of deviation from its projected direction. The more nervous the hand the greater and more numerous will be these deviations. In the hand of one suffering from illness or weak from age the deviations will be most pronounced. To a less degree the same will be observed in a hand which is striving to accomplish something difficult, and to avoid betraying itself by falling into some pitfall. However expert the writer, if the copy is beset with little peculiarities, the tracing will be slower than is his usual habit, and the natural and unavoidable divergence from his ideal will have superadded to it that which comes from decreased rapidity of execution. Like the devia-

tion caused by the wind in projectiles, the greater the velocity of the latter the less will be the effect of the perturbing force.

One peculiarity of these tremors is that in a practised hand they are not easily visible except under considerable magnification. With a power of fifty or sixty diameters they become plain, and little knots, almost unnoticeable before, appear in the writing, which may be partly due to the continued flow of ink from a nibbed pen brought for an instant to a full stop in the course of forming a letter, owing to some feature in the copy which requires a new adjustment of muscles to execute. These appearances will be more fully described in Chapter X.

The natural tremors which can be discovered in free-hand writing are surprisingly numerous, including under that name all changes in pressure on the pen as well as alterations in the direction of its movement. Making due allowance for the irregularities in the paper, which would show variations independent of the muscular action of the writer, there are generally one or two of the grosser kind in every centimeter of average handwriting, and often many more.

The author has observed the evidence of more than twenty impulses superposed upon the force exerted by a writer of moderate skill in tracing the single stem of a long "*f*." Consequently, it is not unreasonable to anticipate that twice that many may be found in the writing of the sick or infirm. In fact, the number of these deviations is concealed by the coarseness of the tracing in which they

are sought. If writing were produced by a very fine-pointed stylus, the number visible would probably be very much increased.

With a previous knowledge of the signature, and the peculiarities which a forger would have to imitate, it is of great importance to note where the hesitation is shown by the examination under the microscope.

If it occur just before the difficult parts are attempted, it will probably distinguish false writing from genuine, because habit will have caused the originator of these peculiarities to write these with as much freedom as any other part.

CHAPTER VIII.

TAPES AND SEALING-WAX.

Use of Tapes.—Where a document of record consists of several sheets it is usual to attach them together by a tape and seal with the purpose of preventing the separate sheets from being detached without bearing evidence of the fact. It has happened that the forgers have not been able to replace both ends of the original tape, but have procured a new piece for one of them. This is a hazardous proceeding, because it is very difficult, if not impossible, to give the same appearance to a piece of tape by artificial means which another piece has attained in a natural way by age and ordinary handling. Even if the colors can be made to agree very well to

the eye, the structure of an old tape is sensibly different from a new one. With continuous handling or rubbing against other papers, with the minute changes which are brought about by the absorption of moisture and subsequent drying, an old tape shows a looseness in its woven texture very different from the compact web of a piece of tape fresh from its roll. (See photograph of tape on the Whitaker will, Plate XII.) The interstices between the transverse and longitudinal strands of a tape in use become enlarged and irregular, and it is not unusual to find the strands arranged in threes or fours together, with larger open spaces on each side of the group. It is difficult to produce this effect with a new tape. It seems to depend upon the character of the fibre which forms the fabric, the number of changes in the hygroscopic condition of the air of the locality where it is kept, and probably on other causes imperfectly known and not yet investigated.

Kinds of Tape.—The tapes in common use are made of linen or silk (the latter being called "taste"). They are usually red.

The differences between these are apparent under the microscope, where the fibres of these substances can easily be distinguished from one another.[1]

Uniformity of the Fibre.—It is important in cases

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[1] For a difference between these two fibres, see the plates in Cross and Bevan's work on the manufacture of paper, or any work on the textile manufactures.

where the tape may have been tampered with to ascertain what the fibre is. It is not likely that a forger will piece out a missing length of linen tape with one of silk, but all parts of this material used on a document should be scrutinized to ascertain whether the material be uniform or nearly so.

If the material is practically the same there may be differences in its condition due to usage.

A part may show the numerous and irregular interspaces, while another part shows the compact structure of a newer tape.

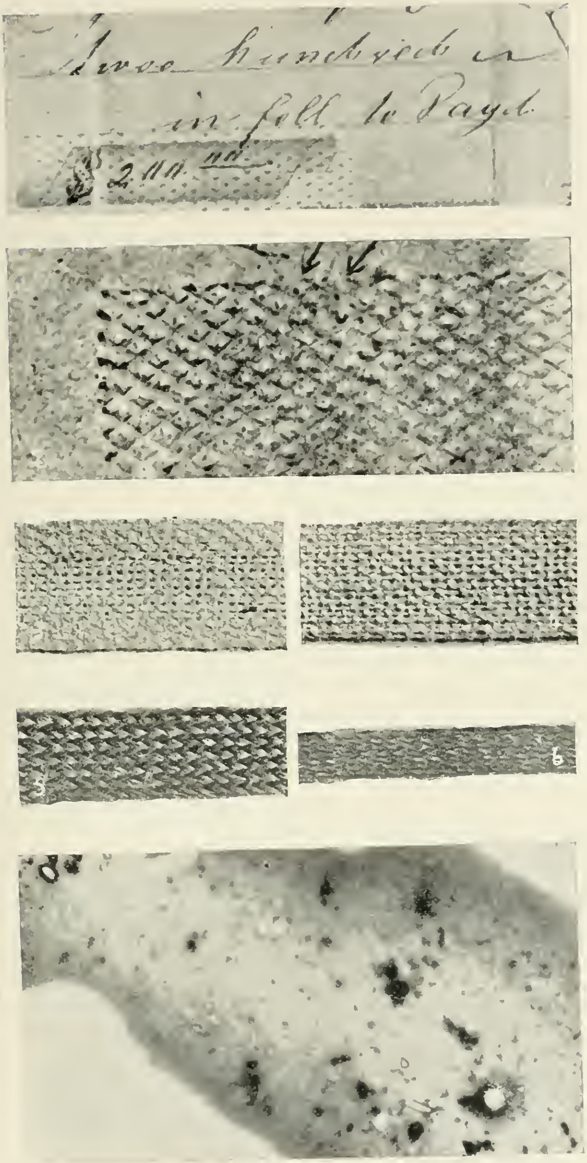
Small particles of sealing-wax or stains of ink may suggest tampering; or the holes through which it passes in the paper may have been enlarged or torn by its passage and repassage.

Plate III., Fig. 3, represents linen tape unstretched, Fig. 4 the same stretched; Fig. 5 represents silk "taste" unstretched, and Fig. 6 stretched.

Sealing-wax.—The three kinds of sealing-wax in use in this country are the American express wax, usually brown, and inferior in quality to the other two, and two grades of red sealing-wax.

If the sealing have been done skilfully, it is very difficult to remove and replace the sealing-wax without allowing that fact to become apparent on close inspection. Remelting is liable to darken the color of the wax, and will certainly round the edges left by the impress of the hard seal. If the wax take fire, it is partially carbonized on top, and the black particles mix with those of

PLATE III.



1 and 2.—Punctured cheque, face and back. The arrow-heads in 2 indicate the punctures over which the "*f*" has passed.

3 and 4.—Linen tape unused, and subjected to tension.

5 and 6.—Silk "taste" (tape) unused, and subjected to tension.

7.—Drop of ink on glass, showing solid particles. Magnification, 35 diameters.

the part which has been softened, and testify to the tampering.

The stamp of a seal on a sufficient body of wax presents the appearance of a depressed cup, at the bottom of which the design of the die is reproduced in relief. The sides of the depression are precipitate towards the centre, and slope gradually from all points of the exterior towards the level of the paper.[1]

Rounding of Edges by remelting.—When the sealing-wax is softened or remelted, the sharp edges of the imprint are always rounded, and if the softening have been over a large part of the wax, the design is distorted or partially effaced, and this is true even if a hot blade have passed between the paper and the lower layer of the wax; the heat from below generally serving to round off and destroy the sharpness of the design.

If, as often happens, the seal has been broken, the very existence of the fracture suggests improper treatment. When the wax has been detached from the tape and remelted to reattach it, a partial burning of the tape may occur, and will furnish additional evidence of tampering; and the same is true as to the underlying paper.

Skin-marks on the Wax.—It might occur (though the chance is remote) that a thumb or finger had been used to press down the soft wax more firmly on the

[1] For information in regard to the manufacture and characteristics of sealing-waxes, see "Die Fabrikation der Siegel- und Flaschenlacke; von Louis Edgar Andés, Wien, Pest, Leipzig, 1885."

paper. If an imprint of the skin should result, it might lead not only to proof of tampering, but the conviction of the forger through the means suggested by Mr. Francis Galton in his book on finger-prints.[1] The evidence adduced by Galton and Sir William Herschel, F.R.S., etc., seems to be that no two prints of the cuticle which covers the thumbs or fingers of different individuals are ever the same, and also that the "whorls," curves, and figures made by the little ridges of epidermis remain curiously constant in the same individual from early youth to advanced age. The method has been used with success to identify American Indians, Chinese, East Indians, and others not easily distinguishable from their countrymen, and in the lucky contingency that a forger identifies himself by leaving a finger-print on the wax, the expert should be prepared to profit by it in the interest[2] of justice.

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[1] Finger-Prints, by Francis Galton. London: Macmillan & Co., and New York, 1892. Also, Decipherment of Blurred Finger-Prints, *idem*, 1893.

[2] A committee appointed by the British Home Secretary, Mr. Asquith, to inquire into the best means for identifying criminals, has reported in favor of supplementing the method heretofore employed in England for the identification of criminals by others, taken partly from M. Bertillon's system and partly from that of Mr. Galton, of recording the impression of finger-tips. The committee accepted as trustworthy Mr. Galton's conclusion that the chance of two finger-prints being identical is less than one in sixty-four thousand millions.—*Daily Press Report*, April 10, 1894.

CHAPTER IX.

DISCRIMINATION BETWEEN INKS BY VISUAL TESTS.

General Appearance of Ink Lines under the Microscope.—In spite of the theoretical speculations as to what a perfect ink should be, it usually consists of two parts: first, a staining fluid; and, secondly, small particles which are suspended more or less uniformly in it.

This can be seen by examining a stroke made with a very black ink on a glass slide and magnified about thirty-five diameters. Here, it will be observed, there is a film which absorbs light, through which are scattered small opaque objects adding to the intensity of its color, and darkening the spots where they lie. (Plate III., Fig. 7.)

Some of these black spots may be due to the dust which has become mingled with the ink by reason of its exposure to the air, but most of the particles are derived from precipitation within the ink itself. The existence of these two sources of light absorption, the colored fluid and the dark particles, offers an explanation of the paler border surrounding ink-marks on badly sized or unsized paper. The reason is that the fibres of the paper act as a filter and prevent the solid particles from penetrating, while they allow the carrying-fluid

of the ink to pass. The fluid spreads by capillary action beyond the line traced by the pen; consequently the line over which the pen has passed, having both the stain and the free solid particles deposited upon it, is darker than the border, which has only the staining fluid.

It is not so easy to distinguish the number of the solid suspended particles on paper as on glass, because the prominent parts of the fibre stained to a darker color by the greater quantity of ink which they absorb are liable to be mistaken for the solid constituents of the ink.

Under the microscope a pen-mark on paper exhibits most prominently the fibre of the paper, which becomes plainly visible as an irregular network, in striking contrast with the adjacent parts of the paper not written on, where the structure is not so apparent.

In all the figures of ink lines thus far shown it will be seen that the fibre of the paper becomes prominent where the ink has stained it, and is not so noticeable elsewhere.

Color.—The first notes to be taken in an examination of an ink under the microscope concern the color: the presence in quantity, or otherwise, of the opaque particles of the ink; the lustre of the latter, and its change (if any) in various conditions of illumination.

It has previously been stated that it is extremely difficult to judge of colors, or the intensity of black by the naked eye. A very low magnifying power will suffice to resolve such questions. High powers are needed in but few lines of investigation to be pursued in the subject we

are considering, but just here a power of sixty or seventy diameters is useful in examining the physical constitution of inks.

The accidental crumpling of a document does not prevent it from being studied under a power of sixty diameters, while the minute characters of the dried writing-fluid appear prominently, and will furnish a means of distinguishing different inks, and even sometimes between marks of ink from the same bottle at different dates. The aniline inks or those in which aniline is a constituent are seldom free from a characteristic metallic lustre, unmistakable when one has often seen it.

Dichroism.—Many inks possess distinct dichroism, or two distinct colors, when illuminated or viewed from different positions. Wherever this occurs the fact should be carefully noted, because it offers a means of discriminating between the ink possessing this property and other inks with more or less the same character and appearance which do not.

Old Ink.—The ink in really very old writings shows a yellowish tinge around the letters which it is hard to imitate. An examination usually shows either no yellow border, or, if there be one, it lacks that gradual shading into the color of the letters which is one of the characteristics of really old writing (*Sittl*).

Changes which occur in the Inkstand.—The chance of getting, whether out of the same inkstand or another, at two widely separated intervals of time, a writing-fluid of the same chemical constitution and physical

appearance is not great. Evaporation and constant contact with foreign substances may alter the character of an ink in a single hour, so that it will not give the same reactions in the same degree or in the same time. It is, therefore, most important to test the character of the ink in the main body of a writing, and in any interpolations, or places where changes in the letters have been made. The manner of making such tests will be taken up subsequently.

But if there be chemical tests which will accomplish this end, a close inspection by means of the microscope will usually divulge physical differences in constitution, color, lustre, etc., which are almost equally important; and besides this, under moderate magnifying power, the junction of the two parts—the original writing and the added marks—is not difficult to find, and will appear unlike the ordinary formation of the character by the writer.

Tests by Light Effects.—It has been incidentally mentioned that the aniline inks have the characteristic of a metallic lustre in the dried tracing which they leave. There are other inks, however, which consist of metallic particles, suspended in the fluid by the addition of gums, which also have this lustre, but it is sufficient here to recall that in almost all cases presented by modern and ordinary writing a metallic lustre is indicative of the presence of aniline inks. Their sediment or tracing possesses also the property of iridescence, or play of colors, which the purely metallic inks do not share. As

a general rule, a metallic lustre and iridescence may be assumed to indicate the presence in some proportion of aniline colors which are often found mixed with other inks. A very small percentage of aniline mixed with an ink will serve to distinguish it from that ink without such addition.

The colors exhibited by inks when seen under the microscope differ from each other much more than a superficial examination would lead one to suppose. It has been before stated that an observer is apt to fail in judging of the similarity of the colors or shades of two inks by the naked eye when one is in considerable mass and the other is represented only by fine strokes. The act of magnifying these objects spreads them out over a broader surface and makes the comparison fairer. One easily distinguishes in writings at different dates well-defined differences of color, even when the same brand of ink has been used, but has been standing in the inkstand in one case longer than the other.

In order properly to appreciate this difference, a color scale should be used, and the colors of the two specimens matched. In most cases no exact counterpart of either will be found, but the nearest matches will be seen to differ, and if the specimens be both of the same ink the difference will be in proportion to the internal chemical and physical changes which have taken place, mainly through oxidation and evaporation.

But the changes of state which occur in the inkstand are not the only changes which produce a difference of

inks, or a difference of the appearance, as a line on paper, of the same ink at different dates. In all inks which contain gums in solution the effect of evaporation in the inkstand is to concentrate this ingredient. The concentration of the coloring-matter may be too trifling to notice when the ink is first laid upon the paper, but that which contains the most gum will be subjected to less subsequent change in a given period, because the subsequent change is due to the oxidation of the air as well as to the actinic action of the light, and the former is hindered by the covering of gum. After three or four months from the date of the writing the ink with least gum will begin to show a slight difference from that which has more, and in three or four years the distinction may be great enough to lead to the conclusion that entirely different inks have been employed.

By Camera Lucida.—Where two writings are to be examined which profess to have been made at the same time and with the same ink, it is well to place them in succession under the microscope with a power of twenty to fifty diameters, in connection with the camera lucida, by passing a color scale under or beside the reflected image until a near approximation to the color of each ink be found and noted.

In this first experiment care should be taken to lay the writings on some opaque object, such as a sheet of metal, or a piece of thick cardboard, in order to exclude all transmitted light.

The author has found it better in this kind of examina-

tion not to employ the parabolic reflector or the bull's-eye refractor for illumination, but to turn the stage of the microscope away from the window or other source of light, in order to get rays as perpendicular as possible to the surface of the object.

By Reflected and Transmitted Light.—When this has been done, a similar examination should be made by transmitted light, if the paper be not too thick.

The colors by reflected and transmitted light will seldom agree, and in general the amount of divergence between two inks will be different in the two cases; but care should be taken not to judge too hastily of the results by transmitted light, inasmuch as there is an unknown quantity, representing dirt, sizing, and natural variation in the thickness of the paper fibres, which must be taken into account.

But, even with these drawbacks, the plan is one which will throw light upon the physical properties of the inks, though without ascertaining on what those properties depend.

Oblique Illumination.—After the two examinations with light as nearly as possible perpendicular to the plane of the paper, in the one case reflected and in the other transmitted, it will be well to repeat the experiment with oblique illumination, using the bull's-eye illuminator for reflected light, the document being laid on an opaque stage; and the concave mirror under the stage arranged for transmitted light.

In many inks side illumination produces a striking

difference from perpendicular illumination in the color, and those which exhibit this peculiarity have been called dichroic. The degree to which this difference appears depends to a certain extent upon the character of the surface of the paper. Where the latter is rough and uneven, it allows more transmission of light from the lateral illuminant through the films spread upon the little prominences, and the changes in lustre and color become more apparent where the surface is perfectly smooth. Still, no surface of writing-paper appears entirely smooth under a magnification of thirty or forty diameters, and appearances entirely unsuspected by the naked eye become manifest under these circumstances.[1]

Colored Prisms.

The plan which has yielded the author the most valuable results is that of examining inks both with and without the microscope through glasses of various colors. If, for example, both inks exhibit a blue tinge, it is because the red and yellow rays have been more absorbed than the blue. If red, blue, or yellow glasses of different

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[1] *Application of Photography.*—Professor S. P. Sharples, of Boston, Massachusetts, has employed a method for the determination of differences in inks not recognizable by the unaided eye, by their actinic effects on a sensitized plate. His suggestion is to make a strong and a weak negative from the writing. If the inks be of one kind, all the marks will appear uniform for each photograph ; but if not, one print will appear more distinct than the other. (See Appendix.)

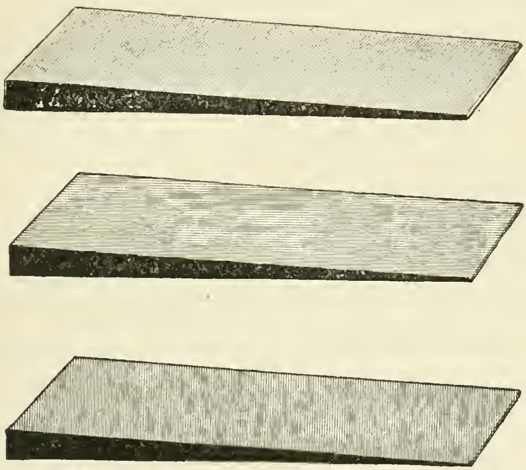
thicknesses be placed over such inks, or, better still, acute glass prisms of these colors be slid over the characters successively to the point of extinction of their color, —*i.e.*, till the written line attains a maximum blackness, —and the units of graduation be read off on the guiding ruler-edge along which the prism is moved, the relative difference in the prevailing color of the two inks may

FIG. 10.

Yellow.

Blue.

Red.



be qualitatively ascertained. For further confirmation of this experiment with a bluish ink, a prism of yellow glass may be used with advantage after the red prism. In case the ink have a yellowish or yellowish-brown color, blue and red glasses or prisms may be employed; and for reddish inks, yellow and blue glasses or prisms. The object of all such experiments is manifestly to establish

differences between different inks in their power of absorption for different colors, and this makes a qualitative determination by colored prisms quite as valuable as similar determinations of differences of color by chemical reagents.

The prisms devised and used by the author for these experiments are 7.5 centimeters in length, fifteen millimeters in width, seven millimeters thick at the base, and 0.2 millimeter at the edge. The corners are all rounded to avoid danger of breaking. The part of a line on which the color-experiment is to be tried is brought to any division-line traced on the graduated white edge of the ruler, or to the middle of the slide-holder, if the microscope be used.[1] It will be found convenient to bring some particular mark of a ruler graduated to millimeters beneath the line under examination, and at such a distance below that the sharp edge of the prism, continuing the mark upward, is also just in contact with this line. By pushing the prism to the right or left, and keeping its lower long edge always in contact with the edge of the ruler, the number of millimeters of movement necessary to extinguish the color may be read

[1] In practice the author employs a boxwood ruler with double celluloid edges, graduated to millimeters, and the graduation marks made as black as possible to assist in determining by comparison with the line examined (which forms a continuation of the graduation mark selected as the zero) when the maximum darkening occurs.

off on the ruler from the assumed zero to the point where the thin edge comes to rest at the moment of extinction.

In cases where the color of the ink is too intense to be neutralized even by five millimeters of one of the colored glasses, and where the object is merely the determination of qualitative differences, another prism, of a color corresponding as little as possible with the general color of the ink, may be superposed on the first (but with its thinner edge turned towards the thicker edge of the nether prism) and slid in a contrary direction until entire extinction of the color is attained.

In using the prisms the writings to be examined should be laid upon a table placed between the observer and a window, if daylight can be used, or in the contrary case between the observer and the source of light, which should be as white as possible. The incident beam should be as nearly as possible perpendicular to the long edges of that plane of the prism in contact with the table. The two lines selected for comparison should be as nearly alike as possible in thickness; and, if possible, the parts of the line examined should be nearly straight, so that they may be placed successively in such a position as to make a continuation upward of the graduation mark on the ruler selected as a zero. The observations should follow each other as quickly as is consistent with accurate measurement, in order that the conditions of light may be as nearly as possible uniform throughout the period of making them. The object

is to ascertain at what point the increasing thickness of colored glass produces the maximum darkening in the line *compared to the field* covered by the colored glass, for this is the point at which the colors complementary to that of the glass have been extinguished by it through absorption. A further increase of the thickness. it is true, makes the lines still darker, but it also makes the field equally so; in both cases through the diminution of light owing to the increase of thickness of the absorbent glass. Some practice will enable the eye to appreciate when this point is reached. When the absorption of the prism is feeble it will be found useful to move it rapidly backward and forward past the point where maximum relative blackness is first reached; gradually diminishing the extent of the excursions until they become only a few millimeters in length, and taking the mean of the readings at the two extremities of each of these excursions, as is done when one desires to determine the weight of a light object on a sensitive balance. When the prisms absorb the rays under examination strongly this will not be found necessary.

Comparative Tests by Color Prisms.—Inasmuch as the number of millimeters over which it is necessary to push a color prism to obtain the point at which total extinction of the predominant color of the ink is reached depends upon the amount and nature of the light, the angle at which it falls on the prism, etc., it would not be possible to employ it to perform the same work at different places or times, or even in different hands, without

providing a standard illumination and uniform methods of using the instrument.

It is also exceedingly difficult to procure glasses sufficiently uniform in color to render this possible without great expense.[1] But the value of the method is not impaired on this account if we use the prisms as we would use an aneroid barometer for hypsometrical measurements without a standard barometer for control. In both cases it is advisable to perform the work quickly in order to avoid changes of surrounding conditions. As a means of determining practical identity or difference it is equal in value at least to a qualitative chemical test.

QUALITATIVE USE OF THE PRISMS.

If the prisms[2] be used to determine the absolute color values of an ink, a table may be calculated, by the

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[1] The prisms of red, yellow, and blue glass are made by Hausmann & Co., 705 Chestnut Street, Philadelphia, and are sold in neat leather vest-pocket cases, designed to protect them from injury.

[2] An instance of the utility of these prisms occurred in the trial of The People *vs.* Roland B. Molineux on the charge of murder, New York, February, 1900. The question was whether certain alterations in exhibits before the court were made with the same ink as the body of the exhibits.

The author was requested to make the chemical tests, but before doing so he examined the two inks under the color prisms. With two of the three prisms the results were practically similar, but with the third they differed, yet not enough to pronounce the inks of essentially different composition. The chemical tests led to a similar result, though six separate tests were made.

aid of the formulas given elsewhere, which shall represent the capacity of the ink for absorption of that part of the rays of a standard white light complementary to the color of each prism, for every unit of the horizontal scale selected; but in the majority of cases which demand simply the determination of the agreement or disagreement of two ink lines in their capacities for absorption, this will be unnecessary, and the observation simplified to noting the points of maximum darkening of the lines *in comparison with the field* under each of the three prisms. The number of units of horizontal measurement over which the respective prisms must be moved in order to attain this maximum darkening will always serve to express differences or similarity between two ink marks, and will generally be sufficient for the object in view.

Especially is this the case in an examination undertaken simply to establish the identity or non-identity of two ink lines,—for here it is unnecessary to give the absolute color value by reference to the lines on the solar spectrum or otherwise, but only the relative action of the same absorbing medium on two inks. In such cases it matters little what the character of the color in the glass prism may be, if it produce a different appearance upon the two ink marks.[1] The main difficulty is to judge the

[1] It hardly needs to be said to those who eschew the Brewsterian theory of three primary colors, and accept that of Young, Helmholtz, and Maxwell, that all color sensation is derived from nerve fibrils in the eye, which may be divided into three groups, sensitive

point at which the colored line ceases to grow darker more rapidly than the surface on which it appears. When this point is reached, a further movement of the prism, bringing a greater thickness of glass over the line, will not increase the relative blackness of the latter, but will merely darken the whole field.[1]

Monochromatic Light.—Finally, it is well to illuminate the writing by monochromatic light, and to examine it when thus illuminated both with the naked eye and with an ordinary hand magnifying glass. Not infrequently a better general idea of the difference of the inks employed can be attained by this method than by examining minute portions of the writing with higher powers.

If the parts of the writing which there are other reasons to consider of doubtful authenticity show, by this test, differences from those parts of which they are the ostensible continuations, additional ground is furnished for suspecting them to be fraudulent.

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to red, blue, and green light respectively ; that there is no objection to selecting a red, a blue, and a green prism for neutralizing the residual color of a ray of light which has passed through the ink film under examination. The only point necessary to observe is that the three prisms together should be capable of absorbing all the escaping colored rays and that no two of them should absorb nearly the same rays.

[1] I am indebted to Dr. George H. Hallett, of the University of Pennsylvania, for a mathematical discussion demonstrating the practicability of using these prisms for the determination of absolute color values of inks, which will be found in the Appendix.

The experiment just referred to may be carried out either in a dark room by means of colored lights, such as the sodium flame made by alcohol and salt, and the red and blue lights of commerce, or in a camera obscura to which light is admitted on top through an aperture, which can be covered by red, blue, or yellow glass plates; or even by laying these latter over the writing placed on a table and illuminated by strong sky-light or artificial light.

The corresponding experiment in transmitted light should also be tried; but here, owing to the large absorption of rays by the paper, the document should be placed on the colored glass and the latter held against a window; care being taken to prevent illumination of the surface. For this purpose an old camera or other box may be used, of which the two ends have been removed. The paper having been laid with the writing uppermost upon the colored glass, the latter held against a window-pane, and a black cloth thrown over the head of the observer and the end of the box, the observations just detailed may be carried out.

It is well to try this experiment with the colored glass first above and afterwards below the writing.

When the paper is thick or opaque, it may be necessary to allow direct sunlight to pass through it.[1]

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[1] Dr. Charles A. Doremus, of New York, has applied the spectroscope to the determination of characteristics of colored inks.

PART II.

GRAMMAPHENY.

CHAPTER X.

MICROSCOPICAL EXAMINATION OF INDIVIDUAL PECULIARITIES OF INK LINES.

THERE are at least three different kinds of deviations from the lines which a writer with pen and ink attempts to execute, one or more of which are always discoverable in his marks, and each of which may be characteristic enough to suggest its author; but frequently with a degree of probability inversely proportional to its size and visibility. The first class includes the gross irregularities and wavering, which can be easily detected by the naked eye, and of which examples have already been shown in the cuts representing the tremors of weakness, fraud, and illiteracy. The first and last of these tremors are allied to accidental blemishes made through the roughness or want of homogeneity of the paper and the defects of the pen and ink. That is to say, a skilled penman may evade these obstructions and minimize their effects; while a weak or illiterate

writer cannot. They need no further description in this place, as they have been considered in the part dealing with general characteristics.

A second class of deviations is produced by what seem to be rapidly succeeding variations of the nerve force exerted on the muscles of the fingers. Assuming this to be their origin, these fluctuations give rise either to extremely minute lateral motions of the pen, causing its apparently straightest down-stroke tracings to resolve themselves under a power of fifty or sixty diameters, and sometimes even with the aid of the ordinary magnifying-glass into a serpentine course invisible to the naked eye; or into variations of vertical pressure giving rise to curious and partially symmetrical widenings and narrowings of the line. Both of these effects may be exhibited in the same writing, or there may be an almost entire absence of either or both of them, depending on the writer's physiological peculiarities, and independently of his skill with the pen. Pending a more thorough study of these phenomena, the author has ventured to call them, provisionally, variations of nerve force. On this hypothesis the first mentioned, or lateral deviations, may result from that action on the muscles of the fingers which causes the pen to oscillate right and left over very minute distances during the writing; the second, or alternate widening and narrowing of the line, may be due to a more or less rhythmic increase and decrease of pressure whereby the distance between the nibs of the pen is alternately

widened and narrowed, and the flow of ink is proportionately increased or diminished for a very brief period. The two kinds of appearances just described differ greatly in number and character in different writings. The lateral excursions of the pen are likely to be least numerous in those composed of short and vigorous strokes, and the changes of breadth of the line in those made of thick lines and especially with viscid inks.

The third class comprises irregularities much minuter than those above described, also possibly due to similar, though more rapid, fluctuations, which require a magnifying power of at least one hundred and twenty diameters to make them clearly visible. These latter irregularities take the form of minute serrations or sinuses on both margins of the down-stroke ink line, but their number is usually greater on one edge than on the other in the lines of any given writer. It is quite possible, in the author's opinion, that these appearances may have the same origin as those of the second class, but in the sense of a series of extremely fine pulsations superimposed on those less fine, which, in turn, are grafted on the macroscopic or visible deviations mentioned in Class No. 1.

As with the phenomena of the second class, so with those of the third class, writings are occasionally found which show very few serrations on either side of the down-stroke ink lines, or which have as many serrations on one side as on the other; but, far from impairing the utility of these features as a means of identification, this circumstance lends them additional significance,—for

these writings are few compared to those containing a preponderance of serrations on one of the two margins of the ink lines, and any such writing is likely to be alone in the small number generally under comparison, and therefore so much the more easily identified.

Thus far, experiment has only resulted in showing a connection between these deviations of the second and third classes and certain involuntary movements of the writing fingers; and also that the position of the pen is an important factor in determining the side on which the greater number of the serrations appears; other, and probably equally important, factors are as yet undetermined. But the fact of the existence of these peculiarities is unquestioned, and the value of the observation where proofs of identity or non-identity are sought, is unquestionable.[1]

If it be attempted to count the number of serrations on each side of the ink line for the purpose of ascertaining which side contains the greater number, it will be found better to select those serrations of medium size when the magnification is one hundred and twenty diameters. It frequently happens that the margin containing the fewest serrations of medium size has one or more of the deepest

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[1] In a case requiring in a very short time the formation of an opinion as to whether several hundred names and words contained peculiarities found in a certain identified writing, the method proved of great value, and the trustworthiness of its indications was abundantly proven.

and widest indentations in the field of view. On the other hand, the very smallest irregularities are liable to be produced by so many and such trifling causes that they have less value for the object now under consideration than those of larger, but not the largest, size. This is especially true when the study is of a camera lucida tracing, for there the involuntary tremor of the draughtsman may be responsible for some of them.

It has been found with regard to those persons whose writing was tested, that if the hollow of the pen was turned towards the right (the left hand nib of the pen thus resting on the paper) the preponderance in number of serrations of approximately equal size will be on the left. If the hollow of the pen be turned to the left (thus bringing the right hand nib on the paper), the preponderance will be on the right; and when the nibs rest with equal force on the paper the number of serrations produced will be nearly equal on the right and left hand margins of the down-stroke ink lines.

More cannot be said at present as to the causes which determine the position of the preponderance in number of these serrations on the right or left margin of the line, but it is not proven that the position of the plane of the pen-nibs towards the plane of the paper is alone of importance in producing this phenomenon. In fact, the examination of lead-pencil marks, which will be referred to further on, where the influence of flexible pen-nibs is entirely removed from consideration, shows the serrations and other fringe-like irregularities which occur with

them to be, perhaps, as prominent as in the lines made with pen and ink.

But besides the preponderance in number of these little tell-tale serrations on one side or the other of the ink line, they give it a peculiar character which seems to be fairly constant, and it is not at all impossible that their forms may by future investigation prove to be peculiar not only to a class of writers but even to the individual who makes them, somewhat as thumb-prints on wax to the possessor of the thumb; though in all frankness the author must acknowledge that he has not yet established so intimate a connection.

So far as he has yet been able to pursue this interesting subject, the differences between the serrations produced by different writers resolve themselves into class differences, like those of the fracture of minerals and rocks. It cannot be said the serrations are those peculiar to *A* or to *B*, but rather that they are of a certain character which various individuals may have in common. The possibility of finally using this feature to identify a particular person will depend upon whether differences of character can be established inside of these general class resemblances, and whether these may be found to lead up to individuals.

In all three classes of deviations from the course of a projected line, the appearances will be modified by the nature and condition of pen, ink, and paper, without altering the essential characters which connect them with particular classes of writers.

PLATE IV.

FIG. X.

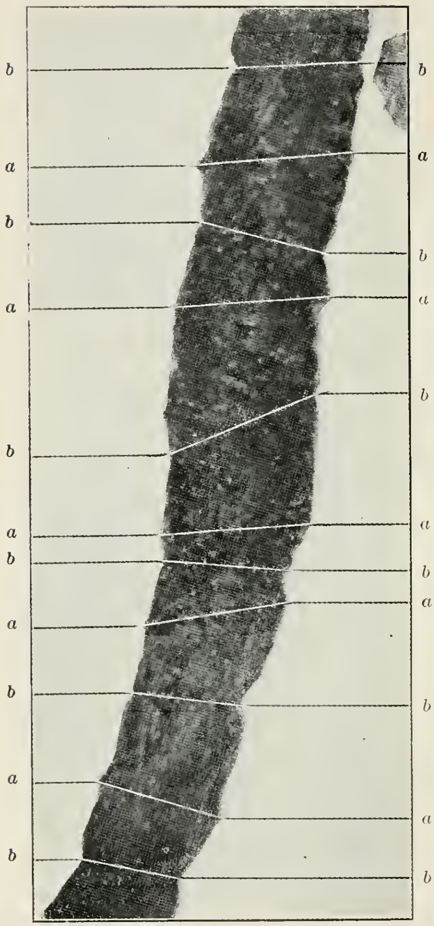
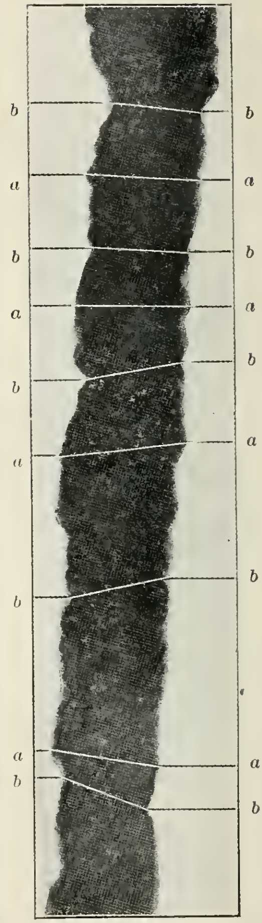


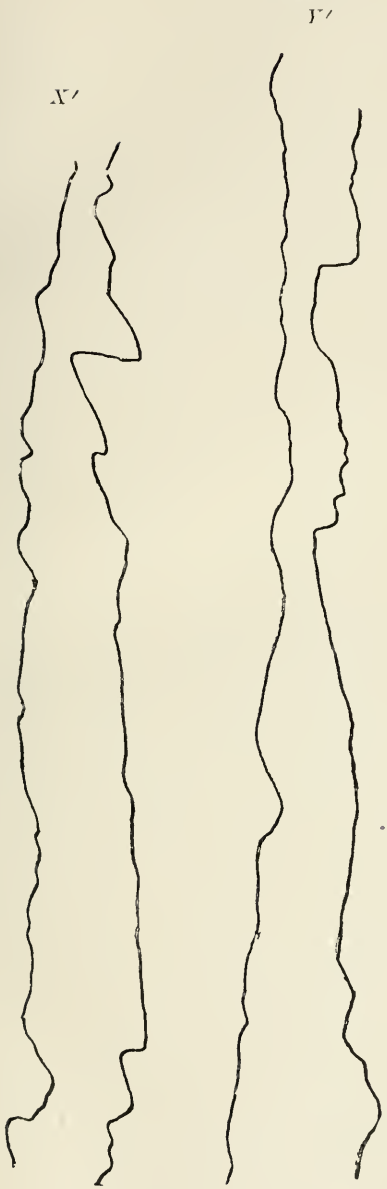
FIG. Y.



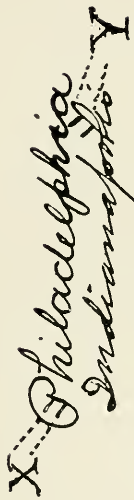
The points *a* show the widest and *b* the narrowest parts of the ink lines. It is to be noted that the maxima and minima of the two margins are not always opposite to each other, but show a tendency to oscillate about a horizontal line, so that the *a*'s and *b*'s of one margin will be observed alternately above and below such line in following the ink mark downward; while those of the other margin will be found in opposite phase. This is made clearer by the white lines uniting the *a*'s and *b*'s of the opposite margins.

This can be accounted for by the simultaneous operation of lateral and vertical movements of the writing hand, which are not coincident in period. To a less degree also this effect might be produced by the slight rotation of the penholder from side to side between the fingers. Magnified 30 diameters.

PLATE V.



Camera lucida tracing of margins of ink lines in the two words reproduced on this page. Magnification, 120 diameters.



Words from which photomicrographs X and Y and camera lucida tracing X' and Y' were taken. The dotted lines indicate the portion of the words represented.

Figs. X and Y (Plate IV.) are photomicrographs of down-stroke ink lines, illustrating both of the deviations described as belonging to Class 2 as well as those of Class 3, or the serrations themselves, though the magnification (30 diameters) is not sufficient to clearly show the latter. The small letters indicate the contractions and the enlargements of the lines, while the tortuous course of Fig. X is quite apparent. Both of these phenomena it is thought by the author may be due to nerve impulses; the first vertical, and the second lateral.

Each of the two ink lines represented in the photomicrographs (Figs. X and Y) was taken from part of a letter in one of the two words "Philadelphia" and "Indianapolis" (Plate V., Fig. 1), written by two different persons.

Figs. X' and Y' (Plate V.) are tracings, by the aid of the camera lucida, of small parts of the two ink lines X and Y under a microscopical enlargement of one hundred and twenty diameters. They show the nerve-impulse (?) marks of pressure more clearly than the photograph, as well as the serrations, of which latter the preponderance in number is seen to be on the left (or doubtful) in X', while it is on the right in Y'. These figures are not given as they appear through the microscope,[1] but as they actually exist in the writings from which they are taken.

[1] The apparent positions of all parts of the object as viewed in the microscope are the reverse of the positions represented in the figure. The right is the left, the top is the bottom. The appearance in the microscope may be obtained by turning the figures upside down.

Figs. *M*, *N*, and *O* are tracings by the camera lucida from parts of a document connected with the first case[1] in which this method of microscopical examination was employed as an aid to identifying different series of pen marks. The tracings by the camera lucida of both vertical and lateral nerve-impulse (?) lines are very clearly and perfectly shown with the same magnification of one hundred and twenty diameters.

Fig. *P* is a line in the same letter examined under the above conditions; but in this case a photograph was used instead of the original letter. It is an illustration of the accuracy of a good photograph in reproducing even the most minute features, since some of the sharply defined indentations cannot represent more than .0127 centimeter (or one-two-hundredths of an inch). The figure itself is an excellent example of the two varieties of the phenomena of Class 2, as well as of Class 3.

A careful study of numbers of these serrations has inclined the author to the belief that they are due to variations of nerve force of great frequency acting both laterally and vertically, as in the cases of the grosser tremors visible under low magnifying power, and of the macroscopic or visible irregularities first mentioned.

The character of the traces left by these supposed nerve disturbances may be changed in appearance by the thinness or thickness of the ink, by the coarseness or

[1] The case of the People *vs.* Roland B. Molineux for murder in New York City, tried February, 1900.

Camera lucida tracings of margins of ink lines in certain exhibits used in the trial of Roland B. Molineux. Magnification, 150 diameters.

Camera lucida tracing of margins of photograph of an ink line from exhibit in trial of Roland B. Molineux.

grain of the paper, or by the stiffness or pliability of the pen; but these variables do not entirely change the individual character of the ink-line structure nor the constancy of a preponderance of the serrations on one or the other margin.[1] This constancy is caused, in part at least, by the position of the pen with reference to the plane of the paper, that one of the two nibs which rests upon the paper producing the greatest number of serrations. If the hollow of the pen be turned to the right, the left hand nib becomes the lower one, pressing with most force upon the paper and tracing the left hand margin of the resulting ink line, in which the greatest number of serrations will be found. If the hollow of the pen be turned to the left, the right hand margin of the line will show the greatest number of serrations. A rough estimate of the rapidity of these tremors may be made from any of the tracings, or from the photographs, by assuming an average distance through which the pen moves in a second, and counting the number of serrations which are formed in that space and during that interval of time.

In Fig. *N*, if we assume that the pen moved with a velocity of one centimeter (0.39 inch) in a second, then

---

[1] It must be distinctly understood that the inquiry is directed always as to which margin of the ink line under examination contains, on the whole (*i.e.*, after the examination of a number of sections), the majority of serrations of approximately the same size. It will usually be possible to find one or two of these minute sections when the general rule is reversed.

during this time there were seven larger and twenty-nine smaller lateral excursions which left their trace in this space (corresponding respectively to 17.5 and 97.5 to the inch). In the same space and time (one centimeter and one second) there were six grosser vertical pressures (corresponding to fifteen to the inch). The minor vertical pressures are not so easily noted, because, owing to the adhesion of the ink to the pen, the release of a slight excess of the fluid by a trifling increase of pressure will be sluggish, and may not be observable when the variations of force follow each other with great rapidity.

Pencil-Mark Serrations.—A very interesting companion note to the preceding observation is the appearance of pencil lines under the microscope. Here the record of vertical pressure is necessarily absent, since there are no spreading nibs to admit a larger flow of fluid. But the lateral deviations are very pronounced, and—what might not have been expected—in almost every case the position of the pencil may be determined by a more or less continuous line forming one margin of the stroke while the other is a fringe of detached dots and marks comparable roughly to the map of an archipelago and a main coast. These detached spots are evidently the minute bosses and corrugations of the fibrous surface of the paper which have been touched and soiled by the solid point of the writing instrument.

In an actual case it was possible to decide without hesitancy that two series of pencil marks were probably not made by the same hand, because the fringe of macu-

PLATE VII.

a

Photomicrograph of an ink line made by Professor Lightner Witmer. Magnified 120 diameters.

PLATE VIII.

b

Photomicrograph of ink line made by hand. Magnified 120 diameters.

The photomicrograph (Plate IX.) opposite this page, of part of a line drawn by a machine holding an ordinary nibbed pen, is introduced for comparison with the lines drawn by human hands. It is magnified about 180 diameters.

The instruments used by stationers for ruling paper are minute metal troughs distributing ink at one open bevelled end. Being rigid, they cannot produce the inequalities of margin due to fluctuations in pressure made by split pens with elastic nibs, the object studied in Chapter X. At the author's request Mr. Hoskins, a stationer of Philadelphia, very kindly permitted the foreman of his ruling department to attach to a ruling frame an ordinary steel pen, after charging it with a black ink. The paper was carried under it by the usual device of a revolving cloth band.

On comparing the photo-engravings of lines made by human hands (Plates VII. and VIII.) with that made by the ruling machine (Plate IX.), it will be observed that the general directions of the right and left margins of the latter are straight and parallel, though each is interrupted by indentations, due to obstructions on the surface of the paper, to faults of ink or pen, or to other extraneous causes. Both the lines by human hands show curvature in general direction, the machine-made line shows none. In the latter there is an almost entire absence of the medium-sized serrations. The alternate widening and narrowing of the line due to unconscious fluctuations in pressure on the pen is also conspicuously absent from the photomicrograph of the machine-drawn line.

These observations, so far as they go, justify the recommendations contained on page 101 as to the selection of the medium rather than the largest or the smallest serrations when comparing the numbers on each margin at a magnification of 120 diameters. The largest indentations may be produced by irregularities in the paper or imperfections in the pen while the mark is being made. The smallest undulations may be the result of so many different causes, and their reproduction in illustrations adds so many more (even to the imperfections of the paper on which the illustration is printed), that they must be discarded as indications of fluctuation in force.

Plates VII., VIII., and IX., offer a strong *graphic* plea without words for the correctness of the hypothesis that the irregularities which have been treated in Chapter X. are in fact due to the writing hand and not to outside accidents.

PLATE IX.

d.

Photomicrograph of a machine-drawn ink line made with an ordinary steel pen, the nibs pressing equally on the paper and being drawn downward. The scarcity of serrations and the absence of curvature on the margins are noticeable. The indentation on the left-hand side is due to an imperfection of the paper. Magnified 180 diameters.

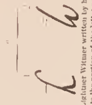
PLATE IX. *a.*

c

Photomicrograph of pencil line made by Professor Lightner Witmer.
Magnified 120 diameters.

PLATE X

Tracings by camera lucida of ink lines *a* 1 and *a* 2. Magnification, 120 diameters



Initials of Professor Lightner Witmer written by himself. The double lines indicate the portion of the letter represented.

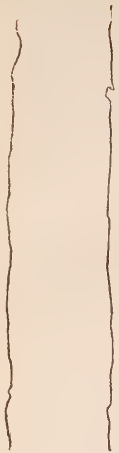
Initials of Professor Lightner Witmer written by one of his correspondents. The double lines indicate the portion of the letter represented.

Tracings by camera lucida of margins of ink lines *b* 1 and *b* 2. Magnification, 120 diameters

Tracings by camera lucida of margins of pencil line from which *c* was photographed and of the "*t*" in Witmer. Magnification, 120 diameters

PLATE X *a*

FIG. 1



Camera lucida tracing of a machine-drawn line. Pen-nibs inclined 45° to plane of paper and pressing equally on it. Direction of motion of pen perpendicular to line of intersection of planes of nibs and paper and downward. Magnification, 120 diameters.

FIG. 2

Camera lucida tracing of a machine-drawn line. Hollow of pen turned towards right. Pressure light. (r l.) Magnification, 120 diameters

FIG. 3

Camera lucida tracing of a machine-drawn line. Hollow of pen turned towards right. Pressure heavy. (r h.) Magnification, 120 diameters

FIG. 4

Camera lucida tracing of a machine-drawn line. Hollow of pen turned towards left. Pressure light. (l. l.) Magnification, 120 diameters.

FIG. 5

Camera lucida tracing of a machine-drawn line. Hollow of pen turned towards left. Pressure heavy. (l. h.) Magnification, 120 diameters.

Plate X. *a* shows camera lucida tracings of machine-drawn lines magnified under the microscope, and lends still stronger support to the above conclusions, as it lacks the irregularities due to the fibre and paper of photographic representations of ink lines at high powers. Comparing these tracings with any of those in this book which were made from lines penned by individuals, the machine origin of the former becomes strikingly evident.

The visible and invisible vibrations of the machine imitate somewhat the unconscious serrations of the human hand due to tremor, and the more closely the greater the pressure on the pen-point; but there is an absence of the raggedness due to vertical pressure; and the edges are much straighter in general direction.

Even in the machine-made line the preponderance in number of the serrations can be made to occur on the right or left margins, as the hollow of the pen is inclined to the one side or the other.

The specimen photomicrographed (IX.) is a minute part of a line ruled by a machine with a medium fine pen, the nibs resting with equal and moderate pressure on the paper.

The line itself at high magnifications, as well as its camera lucida tracing, shows important differences from lines made by human hands.

For the purpose of ascertaining whether the position of the plane of the pen-nibs towards the plane of the paper were an important factor in determining the side of the line which showed the greatest number of serrations, a common steel pen was fitted to a ruling frame and adjusted alternately with the hollow of the pen to the right, and to the left: a light and heavy line being made in each of these positions. (See Plate X. *a*.)

The lines drawn with the hollow of the pen to the right (Figs. 2 and 3) both show a marked preponderance of serrations on the left side. The lines ruled with the hollow of the pen to the left (Figs. 4 and 5) show the same preponderance of serrations on the right-hand margins. In both experiments the light lines showed a greater number of variations from straightness than the heavy, because the tremors of the machine were more easily translated to the pen which was least weighted. But there was an entire absence of the vibration of the pen from side to side which causes the sinuous line almost, if not quite, inseparable from marks made by human hands. The line traced by that nib which rested on the paper (the right nib where the hollow of the pen was to the left, and *vice versa*) in all cases exhibits the greater number of serrations. The line traced by the upper or free nib is less highly indented. But these serrations are different in character as in origin from those which arise from the widening and narrowing of a line by simultaneous but opposite movements of pen-nibs guided by a human hand outward and inward on the two margins, and due to unconscious variations of pressure of the writing hand on the penholder.

lation was uniformly on one side in one series and on the other side in the other. A pencil mark, or the photographic representation of one, viewed under certain conditions in the microscope, looks like an elevated ridge, while it is, on the contrary, a depression in the paper.

The half-tones (Plates VII., VIII., and IX. *a*) represent a portion each of the *L* in the first name of Professor Lightner Witmer, of the University of Pennsylvania, written by himself (*a*), and by one of his correspondents (*b*), in ink; and a portion of the *W* of his last name (*c*), written by himself in lead pencil.

a′ 1 and *c′* 1 (Plate X.) are tracings of parts of the letter *L* in ink and pencil respectively, by the aid of the camera lucida at the same magnification of one hundred and twenty diameters, reproduced in the photomicrograph. The ink letters are reproduced on Plate X.

a′ 2 is a similar tracing of a part of the initial *W* of Professor Witmer's last name written in ink by himself; *b′* 2 is a part of the *W* of his last name written in ink by the correspondent before mentioned.

a 1 and 2, and *b* 1 and 2, Plate X., are photo-engravings to scale of the initials *L W*, showing the parts magnified in *a*, *b*, *a′*, and *b′*: *c′* 2 is a tracing of a part of the *t*

[1] In the Appendix will be found a description of the special apparatus and illumination employed to reproduce these ink and pencil lines without exaggerating by lateral illumination the asperities of surface which would otherwise be too prominent under so great a magnification.

in the same word. All these tracings are made at a magnification of one hundred and twenty diameters.

In order to save space the margins of the pen and pencil lines in the camera lucida tracings (which alone are under discussion) have been crowded together, so that the breadth of the line as seen at this magnification is not represented.

The sections represented in the photomicrographs and in the tracings by camera lucida are not exactly the same.[1]

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[1] The following letter from Professor Witmer explains his views of the subjects which have been discussed in this chapter:

UNIVERSITY OF PENNSYLVANIA—PSYCHOLOGICAL LABORATORY.

June 27, 1900.

DEAR DR. FRAZER,—The examination of the specimens of handwriting which you showed me under the microscope has convinced me that the sinuosities and serrations are individual characteristics related to certain conditions in nerve impulses. I do not think that these serrations and sinuosities necessarily indicate that separate nerve impulses produce the large and small lateral and vertical variations in the outlines of the part of a line seen under the microscope. It seems to me that these are rather to be attributed to fluctuations in what may be vaguely designated neuro-muscular tonicity. These fluctuations will vary according to the medium employed, pen or pencil, and according to the way in which the pen may be held at the time of writing.

It is likely that future research will show that the number and character of these variations are a part of the personal characteristics of an individual. At the present time your method of treatment, which considers the outline as analogons to a specimen of "rock cleavage," would appear to formulate the "personal char-

CHAPTER XI.

GRAPHIC AVERAGE BY COMPOSITE PHOTOGRAPHY.

The method of graphic average or composite photography is based upon the same general principles, but differs from the next in the manner of obtaining the averages, and in the fact that the result obtained is not an answer to the question, "Is the disputed signature probably genuine or probably not?"; but only a design

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acteristic'' element with as much scientific accuracy as the appearance of the outlines justifies. The microscopic investigation of the structure of the ink lines would seem to have present value in contributing to the identification of specimens of handwriting and to point out a line of research that has great possibilities of development. Pencil marks do not appear to me as available for this kind of examination as are the pen marks, because the hardness of the pencil point, its inelasticity, the absence of the flow of ink, and so on, are likely to mask the fluctuations of nervous impulses.

The illustrations which I examined, both the half-tones and the camera lucida tracings, accurately represent what is seen through the microscope.

In a book containing names or other words, written by one hand, or by many hands, it would be possible both from pen and pencil tracings, and perhaps from photographs of them, to employ the maximum number of serrations, relatively on the two sides, and the general character of the outline, as could be ascertained by microscopic examination, to strengthen the probability that the tracings were by one particular hand or by more.

Very truly yours,

LIGHTNER WITMER.

closely resembling the ideal signature, which must then be so employed as to throw light on this question.

It will be understood from what has been already said, that the number of parts susceptible of measurement, called "features" of a handwriting, is practically infinite, since the distance between every two points in the written marks would constitute one such feature, and the best that can be done by the system of measurement and tabulation is to select a very few of what seem to be the most striking features for examination.

But by the application of the beautiful method first introduced to the notice of the reading public by Francis Galton, we obtain not merely the averages of a few selected "features," but one great average of all, made automatically and instantaneously by composite photography. By this process no agreements nor differences between the separate specimens are neglected, and it may fairly be called the method of "graphic average."

If it be conceded that the result of an effort made by a living being, to repeat an action it has become habituated to make, is within certain limits uniform, then the way is clear to study the results of such efforts, and to obtain from their average an approach to the ideal which each of these actions or series of actions was intended to produce, though it never quite succeeded.

If we could divide such an ideal into three component parts, *A*, *B*, and *C;* and if we found that out of thirty efforts *A* has remained constant in twenty-five,

B in twenty-five, and C in twenty-five; while A, B, and C have only appeared together in fifteen cases out of the thirty, we are justified in concluding that these fifteen cases, though they represent but half of the whole number of results, constitute in reality the ideal which the agent has always sought to produce.

Francis Galton was the first to point out in fugitive memoirs, and notably in his important work, "The Human Faculty," that one could sift the common from the accidental features of a number of objects by exposing them in succession to a sensitized plate in such a manner that the images of the similar parts of the different objects should occupy as nearly as possible the same parts of the plate; and that each object should be exposed for only a fraction of the length of time necessary to complete a picture on the film used. This fraction depended generally, if not always, on the number of objects and on the sensitiveness of the film. For example, if there were eighteen objects and the plate took thirty-six seconds to develop, each object would ordinarily be exposed for two seconds. The result in the finished picture would be that those features which all the objects had in common would be reinforced by each separate exposure, whereas those which were accidental, or varied for every individual, being exposed for but two seconds, or one-eighteenth of the time necessary to make a perfect picture, would be so indistinct as practically to disappear. Where the object was to fix a family type by photographing all the

members, male and female, on the same portion of the plate, the result is a curious medley of faint whiskers and moustache; of hair parted in the middle and at the side; of female gowns with buttons to the throat, and of male shooting-jackets thrown open. But out of all this faint halo of confusion and blur there starts a characteristic face which is the family type. Very often, too, this type-face resembles both of two different members of a family between whom by direct comparison no one can find a resemblance. It is this latter fact (which might have been expected) that induced the writer to look to the process for aid in solving the problem of identity of origin in handwriting. When a number of animals of the same race are thus treated, the method fixes the race characteristics; when a number of patients suffering from the same disease are treated, the traces peculiar to this disease are emphasized, etc. When a number of pictures or coins bearing different representations of the same individual or scene are the objects, the result is to obtain either the average appearance of the same thing under different conditions (as, for instance, one man at different times of life), or the average of the impressions made by identically the same thing on different artists. In this latter case the merit of the process is that it constructs its image out of all that many pairs of trained eyes have seen, without giving undue weight to any one pair. So far, then, these efforts have been directed to recovering a lost or concealed existence through multiple testimony, very much

as the law tries to get at the truth by examining a number of witnesses.

A line made by a human arm and hand is liable to the variations which such an arm or hand must produce when influenced, as it almost always is, by indefinitely numerous disturbing, physical (and mental) forces. A line so produced on paper is as much a resultant of organic processes as the outline of the human figure or the expression of the human face. It is a kind of fossil, like the print of a footstep or of a leaf which, though it consist of nothing having life, or that need ever have had life, and though it possess none of the material of the body which made it, is capable, like the other fossils above referred to, of telling a great deal of the characteristics of that which produced it. It is, in fact, as organic as the external forms of living things by which we judge them, for neither do these outlines and surfaces possess life.

With a given mental image before one of what is to be written, and with a constant relation of will-power, nerve sensitiveness, and muscular force, the same word could be exactly reproduced a thousand times by a writer, provided that all these conditions were invariable, and no others were superadded. So far from this being the case, however, every one of the above conditions which influences the production of a written word is constantly varying. The movement commenced to effect an up stroke is interfered with by an unexpected obstacle in the paper, a slight twinge in the shoulder or the unconscious start caused by a sudden noise,

etc. The resulting line shows (did we sufficiently understand the detailed working of all the complicated parts of our mental machinery to interpret it) just the order in which our different sentient and executive functions have been affected, to what extent, and in what manner. But while these ever recurring accidents result in preventing any word from being made exactly as it otherwise would have been, the fact that no two of them represent the same kind or amount of deviation leaves it still in the power of the experimenter to extract by this process the "ideal" writing,—a writing which probably never was seen precisely as it appears in the composite, and yet which so combines all the visible results of a particular will acting on a particular arm to trace on paper a known design with a pen or pencil that it may justly be called the *type* chirography of that writer. What was said of the resemblance of every individual of a group of related objects to the composite made of them all, even though it differ widely from other members of the same group, is true of handwriting. It has been remarked that the composite signature is an ideal, and never was realized. The lines along which the strongest reinforcements are made are those parts of the signature where the pen deviates least frequently from a certain course. Let us suppose the signatures *a*, *b*, *c*, and *d* to be in agreement as follows. At the point *l*, *b* does not coincide, but *c* and *d* do. At *m*, *c* does not coincide, but *d* and *a* do. At *n*, *d* does not coincide, but *a* and *b* do. The tracing which would repre-

sent to the eye part of the ideal signature would be that traversing the points l, m, n, because each of those points having superposed lines of three out of the four signatures would be darker than other parts of the writing, while the variations would be indistinct.

In examining with care such a composite signature as has been just described, the attention is at once arrested by the fact that the variations are not equally distributed over the entire body of the letter, but that there are regions of each letter where variations of a particular kind are noticeable, and other regions where there are few or none. The greater the number of writings of an individual compared the more obvious does this fact become, until one is tempted to conclude that after a handwriting is once formed it cannot *naturally* exhibit deviations except within defined limits and in certain small areas adjacent to the separate letters. It is thus as important to the comprehension of the character of a writing to study the variations and their limits, as to study the ideal writing. Indeed, the variations are all-important in the matter of identification, and if there were no variations the method would be inapplicable, because an exact copy of any word might be made, for example, by tracing. The kind of variation is easily observed where there are a number together. The most perfect adept at forgery could hardly hope to simulate the microscopically minute variations which are simply the visible expression of a series of indefinitely complex influences of certain nerves on particular muscles.

Composite photography is a method of obtaining the *essence* of a number of objects, and, in so far as those objects are related, of recording their relation to each other. The objects thus generalized are the results of the action of a certain force or certain forces on matter.[1]

The signature or the merely formal and always repeated parts of a letter of correspondence or other document have an entirely different determinative value from those parts which are composed of words and letters thrown together in an order which may never be repeated. Separate words can be selected to form bases of composites, or even the two or three words which enter into an idiom,—that well-trodden short-cut of language to a given idea. Partial phrases, by any one accustomed to write much, rendered frequently in other languages by a single word, such as "in order that," "as well as,"

[1] In a pleasant letter received from Mr. Francis Galton, F.R.S., with his acknowledgment of the receipt of a copy of the paper on this subject which I sent him, he mentions that an attempt was made at the Kew Observatory to apply the principle of composite photography even to the meteorological charts, without great success, though with more than Mr. Galton would have anticipated.

A more recent and fortunate application of the principle appeared in the *American Geologist* for April, 1894, where Mr. J. M. Clarke mentions the successful use of this method to procure a "fundamentum" for the variations of *Leptodesma*, a genus of lamellibranchs occurring in the Hamilton and Chemung stages. The strongest lines in the composite correspond nearly with *Leptodesma Rogersi*.

"not only," "but also," etc., may be taken as elements for the construction of composites, but the constancy in form of such elements is not as great as that of the signature and the few formal words which precede it in an epistle. There are several reasons for this: one is that these formulas occur in different connections with the accompanying text, indicating very different attitudes of mind in the several cases. The sense of what is written must have a large influence in the manner of writing it, and therefore the letters composing these words will be larger or lighter, or more or less quickly and irregularly written, as the idea conveyed evokes different emotions in the mind of the writer, yet the characteristics which connect the writing with him will never be wholly lost. A circumstance equally noticeable will be the place which the words occupy on the paper, whether where there is an abundance of room to write the words, or where they are cramped in order to bring them into a smaller space. In cases where the words of such a subphrase are divided between two lines, they will almost surely not appear as they would when they follow each other in their natural order. But even more than these is the fact that the signature and its connected words, "Yours truly," etc., are always indicative of the task completed, the information conveyed. They are words of ceremony and farewell, no matter what the contents of the letter may be, and being invariably repeated they come to be a purely conventional sign. This symbol usually occupies

very nearly the same part of the page,—at least as to its distance from the right- and left-hand edges of the paper, —and this tends to give it a certain distinctive character. All these facts lead to a difference in appearance between a signature and an original composition by the same hand.

There are, of course, peculiarities in every handwriting which can be traced both in the signature and in the body of the text. These are very apparent when the writer labors under a physical disadvantage, such as a maimed or deformed hand or arm, but in lesser degree they are present in every handwriting, and constitute the general resultant of "will-power, nerve sensitiveness, and muscular force" employed by a given individual in this perfunctory habit.

It is not always entirely obvious how signatures with many light flourishes, or accompanied by intricate lines connecting their several parts, should be superposed; for these appendices are so easily affected by minute causes that it seldom happens that two will cover each other exactly. It is not to be expected that such parts will survive in the resulting type signature, but the breadth of the space covered by the blur, and the parallelism of the faint lines will give evidence of the extent to which these ornaments have grown from caprice to a habit.

As a general rule, there are several places—sometimes as many as eight or nine in a long signature—where the maximum darkening of the lines indicates a general conformity of the pen's path to one direction, and it would

seem that these places were not peculiar to any one part of a letter, nor less in a hair-line than in a heavy stroke. They appear to be dependent upon the anatomy and muscular structure of the individual, and his method of performing the act of writing his signature. For instance, some writers can only form one or two letters without moving the writing hand, and only a word or so without shifting the elbow; others describe with the forearm of the writing hand a curve around the elbow, which latter remains stationary; others slide the forearm along into parallel positions while writing. All these habits have different effects upon the handwriting, though they are not always to be easily detected, owing to the fact that other habits are cultivated at the same time to counteract the defects which each of these methods, when not so compensated, would have impressed upon the appearance of the chirography.

Thus, he who writes with a definite part of the arm pivoted immovably upon the table must learn to move the fingers over a greater space at some part of the line, to avoid the curve which would unconsciously result. This more vigorous movement of the fingers is naturally likely to produce heavier strokes in the part of the signature where the compensation is applied. So that a fixed forearm and heavy letter in the middle of the signature may stand to each other in the relation of cause and effect.

Methods of making Composites.—There are at least two methods of making composites. The first was suggested by Mr. Galton, and consists in exposing the sen-

sitive plate to each of the objects in succession for a fraction of the time necessary to produce the negative, care being taken to bring similar parts of the images formed by the lens over the same part of the plate. The plate will be exposed to each object for a time equal to the number of seconds required for a complete exposure divided by the number of objects.

This plan is preferable, and in fact necessary, where each object supplies details to a large part of the surface of the sensitive plate included by its outline.

The second method, which is applicable to linear designs like handwriting, consists in photographing each object on a film of gelatinized celluloid and making a composite by superposing these films, and photographing them all together when thus superposed.

If the number of authentic signatures from which the composite is to be made is very large, they are sorted into different lots, each lot consisting of words having approximately the same dimensions, and composites are made from these lots, care being taken to make the resulting composites equally long by altering the distance of the objects from the camera where necessary.

Composites can be made of these first composites again until a final plate is secured representing the composite of all the genuine signatures employed.

Such a final composite will appear as a heavy, thick-lined signature, which, nevertheless, exhibits very strikingly the peculiarities of its writer's hand.

Where extreme precision is required, or in cases

where the writing is so wide and loose that good composites of the two or more names as a whole cannot be obtained, it will be necessary to make a composite of each name, or even of each letter separately, and to study the suspected writing name by name, or letter by letter.

This plan, while more laborious and expensive, is much more certain to lead to good results, because it deals with each element of the complete signature separately, and not with groups of them together. But in most cases the treatment of the whole signature or each name as a unit will yield important data for deciding as to its genuineness. A composite of each name of a signature will obviate the difficulty of dealing with too great a number of variables at once; and this method is preferable to the analysis of the component parts separately, because there is a character in the way in which the letters are strung together which is overlooked when they are considered each by itself.

Mr. W. Curtis Taylor made the first composites of signatures for the author, and also the composite of the Washington signatures, accompanying a paper on this subject, presented to the American Philosophical Society in 1886. (Plate XI., No. 4.)

This composite was made by Galton's method of exposing each of the objects to the same sensitive plate for less time than is necessary to develop it.

More recently Mr. Charles Truscott has prepared another composite from the same signatures by the method of superposition.

The method of examining by composite photography is to be recommended wherever applicable, because it includes all the elements of character in a handwriting, and not merely a selected few; because it eliminates the personal error of observation and measurement, and represents everything in the final result which existed in the separate cases.

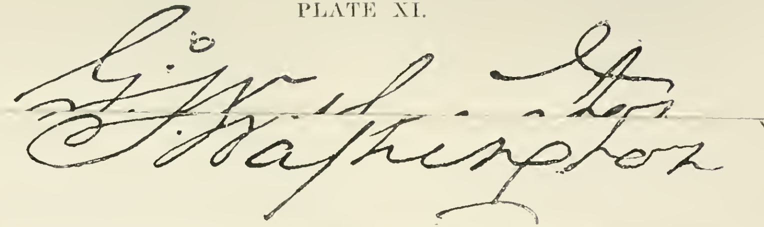
In this it is even better than the tables drawn up to represent the numerical averages by measurement, because it appeals at once to the eye and requires no previous knowledge of even the simplest mathematics. It would seem, therefore, when properly employed, and not abused, or strained to procure results which it cannot legitimately give, to be simple and reliable, and, if the photographs have been honestly and wisely prepared, it removes the personality of the expert from the case altogether.

Washington's Signature.—George Washington's signature has been selected as an illustration, because many persons are familiar with it, and there are numerous well-authenticated documents in existence which bear it. It is, however, a severe test of the principle because of its length, and the dash and freedom with which it was written.

In writing his signature Washington put pen to the paper five times. First he wrote the "G W" in one connected line. Second, he raised his hand and made the small "o" between the upper parts of the G and W, and the two dots which appear in all but signature No. 7.

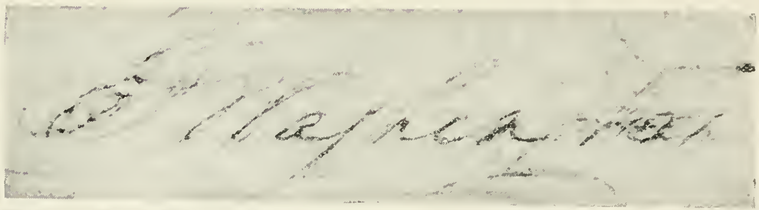
PLATE XI.

No. 1.



Two kinds of composites of the above seven signatures.

No. 4.



No. 4a.

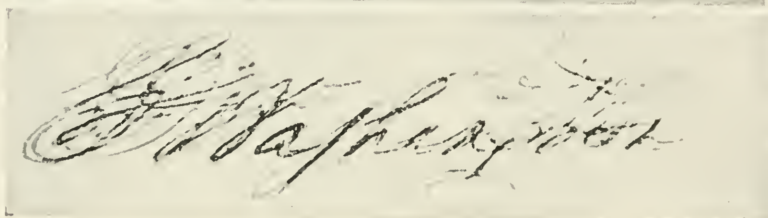
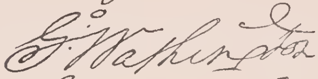


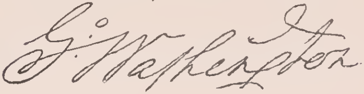
PLATE XI

No. 1

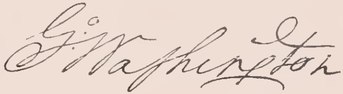
No. 2



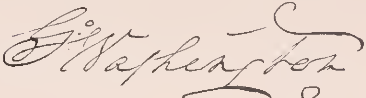
No. 3



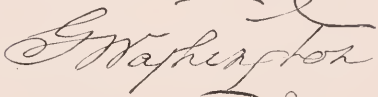
No.



No. 6



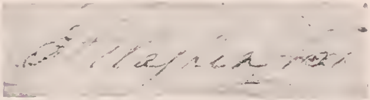
No. 7



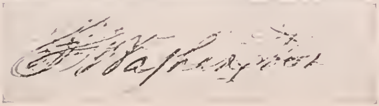
No. 8

Two kinds of composites of the above seven signatures.

No. 1



No. 1a



Third, his arm and hand were placed in position to write "ashing," these six letters occupying a breadth of almost exactly 4.5 centimeters (or 1.76 inches) in every signature except the third, where they are extended to 4.7 centimeters (or 1.84 inches). This is about as much of the arc of a circle, of which the centre is some part of the forearm pivoted on the table, as one with arms and hands of average length can cause to coincide with the tangent, or the base line of the letters, unless unusual effort be made and a great deal more movement be given to the fingers. The "g" ends in a curved flourish, of which the convex side is turned upward below the right centre of the name.[1] Fourth, he wrote the final "ton." Fifth, he added the very peculiar flourish above the right centre of the name, with the object of dotting the "i" and crossing the "t" at the same stroke.

In examining the composite, the effect of these various separate movements becomes manifest in its strengthened portions. It is hardly possible that any one during the period of sixteen years which these signatures represent, or from 1776 to 1792, should have so schooled his hand to write a long name that the first three or four centimeters of the writing should always occupy the same relative position to the body of the signature. It would take at least that much action for the hand and arm and pen to be

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[1] The lower loop of the "g" in all the signatures and in the composites was cut off in preparing the plate.

brought into normal signature-writing condition; and especially is this so when the part of the writing we are considering is accompanied by flourishes, as is the case. The "G W" and the little "o" and the dots at the top were the prelude, after which the arm was moved into position to write the main body of the signature, or the "ashing." Of course, from the manner of making the dots, and the extremely small space they cover, their reinforcement of each other in the composite was almost impossible, and, in fact, like other subordinate characters, they disappear almost completely. The "ashing" is the part of the name one would expect to exhibit the greatest amount of uniformity, as it actually does, with the exception of its terminal "g," which shows more variation than any of the other letters, because at this point the limit of coincidence between the tangent line of the writing and the curve, of which some part of the right forearm was the radius, had been passed, and a freer movement of the fingers was compensating for the increasing divergence.

The fourth separate act of the penman was the formation of the "ton" after changing the point of rest of the arm. The breadth of the space occupied by these three letters is from 0.75 to 0.87 centimeter (0.29 to 0.33 of an inch), and considerably within the range of coincidence of the curve and tangent line of writing before referred to; owing to this fact, there is only a moderate degree of reinforcement of the letters in the composite, because these letters might fall into the first or last part of

the five centimeters of space which was the limit of movement with a fixed elbow. It is worthy of note that even in this case the middle letter of the three is darker in the composite than either of the outside letters. The fifth and last movement was the flourish which dots the "i" and crosses the "t" by one stroke. This was done in the freest manner, often, as it seems probable, without resting hand or arm on the table at all. Therefore there is no coincidence of the lines in this part of the composite, and the *region* of variation is wider than that of any other part of the signature.

All the original signatures used in preparing the accompanying plate (XI.), seven in number, are unquestionably genuine. They were carefully chosen from a number of authenticated signatures in the possession of the Historical Society of Pennsylvania, with the exception of No. 2, which is the property of the author.

No. 1 is on a letter dated December 18, 1776, from near the Falls of Trenton, and addressed to Washington's brother Samuel.

No. 2 is on a letter dated Head-quarters, November 4, 1777, and is addressed to the author's great-grandfather, then Lieutenant-Colonel Persifor Frazer, and a prisoner of war in Philadelphia.

No. 3 is on a letter dated September 27, 1777, and is to William Henry, of Lancaster.

No. 4 is the composite of all the signatures by Galton's process of using one sensitive plate, made by Mr. W. Curtis Taylor.

No. 4*a* is the composite of 1, 3, 5, and 8, made by Mr. Truscott, who photographed the superposed positives on celluloid strips.

No. 5 is on a letter dated Head-quarters in Morristown, February 22, 1777. The person to whom the letter was addressed is not stated.

No. 6, dated September 26, 1793, is affixed to the commission of David Lenox.

No. 7, of the same date, is affixed to David Lenox's appointment as agent for the relief and protection of American Seamen.

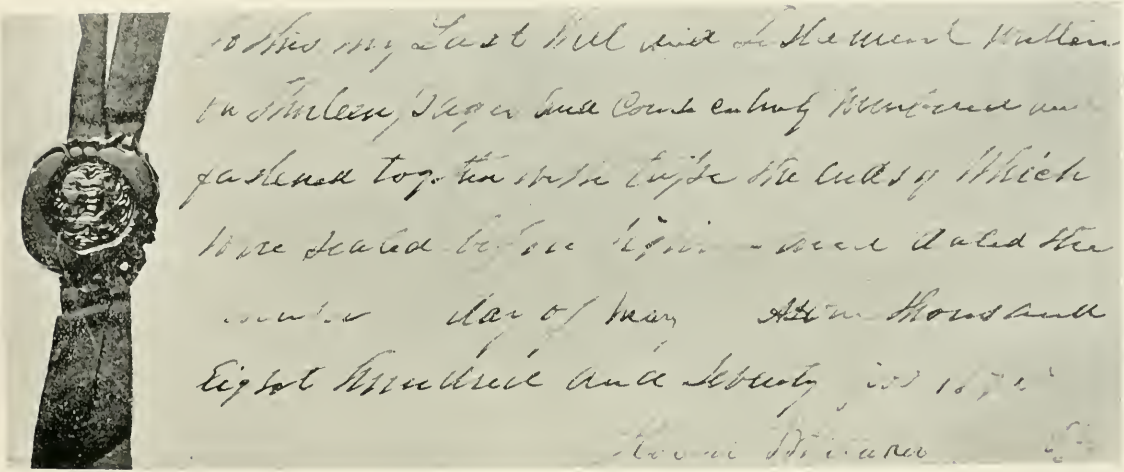
No. 8, May 24, 1799, is on a letter to Thomson Mason.

The next composite is made from a number of genuine specimens of a signature. A photograph of a forgery of this signature, attached to a document, is placed beside it.

The copy of the seal, signature, and the concluding lines of the last page of this famous document has been made from a photograph kindly loaned to the author for that purpose by the late Judge F. Carroll Brewster; the original document, now in the possession of the Register of Wills of Philadelphia, having been too much soiled and mutilated to furnish a satisfactory copy.

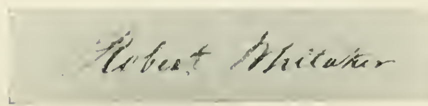
The signature affords a further example of the tremor of fraud,—*i.e.*, that tremor and uncertainty which result from the slow motion of the pen over the paper, necessary to a hand unaccustomed to writing a signature

PLATE XII.



to this my Last Will and Testament written
on thirteen pages and [illegible]
fastened together with tape the ends of which
were sealed before [illegible] and dated the
[illegible] day of May [illegible] thousand
Eight hundred and seventy [illegible]
[illegible]

Composite of genuine signature of



when all the minute details visible in that signature must be repeated. Still, it would have been hazardous to pronounce the name a simulated signature, in the absence of genuine examples.[1]

Under a moderate magnification the continual changes in the pressure of the pen on the paper and the constantly recurring deviations in the pen mark are sufficiently manifest, and with the light which has been shed upon the history of the forged signature it is impossible not to ascribe them to their proper cause: but in the absence of such light it would be claiming too much to profess the ability to discriminate always between the halting and uncertainty due to fraud and that due to feebleness, or illiteracy, or other unknown cause.

The composite of the name was obtained from five signatures to letters written long before the period of the will (1849–54). Perhaps among the voluminous testimony taken in this case the observation may be found that Mr. Whitaker had adopted the habit of writing his name "R. Whitaker" for a long time before the date of the will, and that during the period previous to this when he wrote his name "Robert Whitaker" he employed a final "r" different in kind from that attached to the will. The character in the name appears clearly in the composite, and differs from that in the signature entirely.

[1] An allusion to the tests of the ink of the alleged Whitaker will by methods devised by the author, but since then often applied, will be found in the chapter on Chemical Examination.

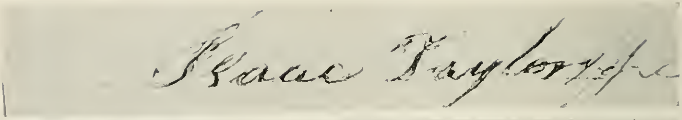
Each name of the signature was photographed separately for a composite, and the two were joined by careful measurement of the relation between the names in the genuine signatures. The photographs were made by Galton's process of exposures of the successive objects to the same plate, each for its fraction of the time necessary for complete development.

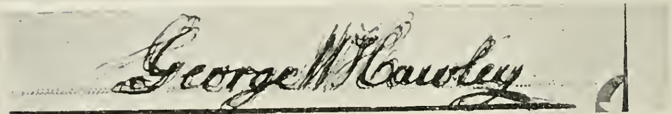
This furnishes a good illustration of the pitfalls awaiting the forger, who, in spite of his cleverness, usually leaves evidence of his unlawful work.

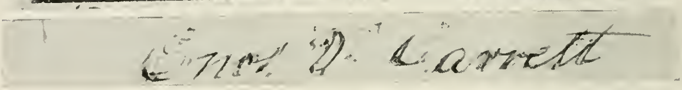
The dragged and manipulated appearance of the tape may be compared with that of the stretched tape shown in a previous chapter, while a close inspection will reveal a scratch across the face of the "D" on the seal, which played an important part in the trial.

Use of the Composite.—When the composite has been made, it should be submitted to the same measurements as the separate signatures, though it will not usually be found so tractable. The portions of greatest value in determining the elements of the given handwriting are those which are the blackest, because they indicate the most constant routes of the pen. It is more difficult to measure spaces between letters in the composite, because its dark kernel is broader and less well defined than the similar parts of a single signature, and it will in fact often cover nearly as much paper as the space itself. In general, wherever a column representing the measurements of the same element in different signatures shows large variations in the

PLATE XIII.

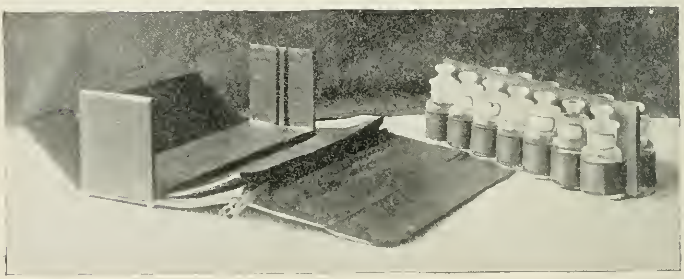
1 

2 

3 

4 

Composites of signatures.

5 

6 

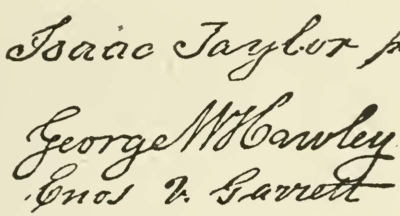
Portable reagent case.

numbers, the said element will appear in the composite as a broad blur or as a number of distinct lines.

It is advisable not to attempt to get a measurement thus obscured from the composite, but to rely for the expression of its average on the numerical mean obtained by measuring individual letters or distances between them. In Plate XIII. will be found composites of genuine signatures of Isaac Taylor, George W. Hawley, and Enos V. Garrett, which when compared with the forgeries of their names (Fig. 11) illustrate the use of the process in detecting fraudulent writing.

The signature of Thomas J. Morris was made from twenty-seven undisputed examples written by him during

Fig. 11.



a period of eight or ten years. The agreement in these signatures was so great in parts of the name as almost to amount to coincidence. The black lines without blurs represent the ideal of the writer's signature which he never attained entirely at any one time, and the blurs indicate local and accidental deviation of individual signatures from that ideal.

It will be understood from what has been already

said that the measurement of the composite is not the only, nor perhaps the most important, aid it can render. To a jury it furnishes that most valuable of criterions, an authentic pattern of the ideal signature, while to the expert it gives the kinds of variation, their distribution in the separate letters, and their limitations. In Table I., p. 150, the agreement of the numerical and the graphic methods and of both with a previously unrecognized genuine signature is strikingly shown.

CHAPTER XII.

QUANTITATIVE METHODS.

Insufficiency of Other Methods.—Up to the present, the means suggested for the examination of documents have been qualitative, and the results have been attained by impressions on the senses, which at most have been comparative. This signature has been observed to be more freely written and the other more labored; one line has been observed to be over another; one ink bluer or blacker than another and therefore different from it; this and that peculiarity of formation of a letter or word, or a sentence, is or is not found in both writings.

Such methods serve a most useful purpose, and if many of them point to the same conclusion they may succeed in carrying conviction to the mind, as, for in-

stance, in Chabot's study of the letters of Junius, often before referred to. But they have the disadvantage that if their indications are contradictory they do not aid in reaching an opinion, and necessarily leave out of consideration all cases which in themselves are inconclusive. If, for example, it be desired to compare a genuine writing with one in dispute for the purpose of ascertaining the differences in their characteristic features,[1] by what method is a typical signature to be selected? It is not uncommon to find the most salient feature of a man's ordinary signature very much modified, if not actually suppressed, in some few cases, and who can say whether or not the specimen given as a standard is one of these?

If a search be made through a series of undisputedly genuine signatures, it will be found that one characteristic fails in one specimen and another in another.

In few if any signatures of a man throughout his life are all the features which combine to constitute its character present at one time. Under these circumstances the selection is an arbitrary proceeding.

Is there any way which can be adopted to overcome these difficulties, and to avoid incompatible indications while making use of all the material which can be procured?

It was the author's conviction that such a way could be found which induced him some years ago to take up

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[1] An act, be it understood, which must be performed in the privacy of the expert's study or laboratory.

the study of handwriting separately from investigations of the materials used in producing it.

The introduction of the experimental method into all modern investigation (biology, anthropometry, psychology, etc.) to replace disputatious metaphysics, and the vague indications of subjective impressions, led to the hope that in this difficult subject also means would be found to apply measurement and the simpler forms of averages and ratios as well as the mathematical expression of probabilities. That such treatment of the subject is in the interest of justice hardly needs to be said. As long as the steps by which experts reach their conclusions are assumed to be so intricate or recondite that only the results may be stated, just so long will the character of expert testimony suffer in the opinion of the public.

METHOD OF AVERAGES AND RATIOS.

Three Postulates.—Three postulates may be safely laid down.

1. Everything capable of being observed is capable of being measured, provided one can find the appropriate instruments and methods.

2. Where similar objects, produced under variable conditions, are to be observed, the method employed must be capable of separating that which is essential from that which is accidental ; and such a method is the determination of the average and the maximum variation on either side of it.

3. The determination of averages with limits of variation is applicable to the study of handwriting, and especially of signatures, because handwriting is a result of the action of a motor (the will) on a machine (the bony structure of the arm with its particular muscles, etc.) attempting to reproduce a pattern which habit has gradually rendered permanent in the mind. The variations in the will-power and accidental external hinderances, such as a bad pen, rough paper, lack of space, etc., may modify this pattern in one or more parts, but almost always more characteristics will remain than are removed by these causes, so that the addition of every genuine writing to a number of other genuine writings will raise the average measurements of them all to closer conformity with the ideal of the writer, if only by a little.

Numerical Average.—Instead of selecting a single writing to serve as a pattern, and comparing the doubtful writing with this, it is better first to ascertain the parts of the genuine writing which are most worthy of measurement. By measuring these in every feature, and taking the average of all the observations of each, one gets a numerical expression of each feature, which is near to the ideal which the writer always strove, but without complete success, to attain; and the approximation will be in inverse ratio to the variability of these features.

This method is adaptable to all cases where the number of authentic examples is great enough to give weight

to the average deduced from them, and may be called the method of numerial average.

The selection of the characteristics for measurement will shortly be considered.

Ratios.—In connection with the method of obtaining averages of the characteristic features of a number of genuine signatures, and of comparing these averages with the similar measurements of the disputed signature, is the deduction of a ratio or proportion between the lengths, heights, angles, etc., of different parts of the genuine signature. Both of these methods will be explained later. The particular value of ratios of parts in detecting the genuineness or fraudulency of a writing lies in the fact that while they are from their nature unseen and unsuspected by the forger, they are most likely to be involuntarily preserved by the genuine writer, and most unlikely to be produced by any other hand.

Measurements.—It is not a matter of indifference what points be taken in measuring, but there are rarely any entirely devoid of significance, and the more numerous the measurements, the greater will be the accuracy of the description, and the larger the number of average agreements or disagreements with the writing in dispute, depending upon whether it is or is not genuine. In selecting a few parts of words or letters for measurement, care should be taken that they be not too near together, or of a kind to cause one to suffer from the distortion of the other. Where two subjects of measurement, for instance, are adjoining letters, the abnormal flattening of

one will be likely to cause the same in the other. This makes less difference, however, if a large number of specimens are measured.

Some experience in this work will suggest the lengths, breadths, distances, spaces, heights, and angles which are most characteristic, or likely to be important. Previous experience in the office-work of topographical surveying or mechanical, or architectural drawing, will be a valuable aid to the student of handwriting. Only some such experience will enable him to overcome the difficulties of dealing with coarse and irregular ink lines, and determining their beginnings and endings, the point of their greatest extension to the right or left, and their general direction; for they are usually much thicker than the lines on the protractor which they are made to join.

It is not uncommon for a writer to adopt some peculiarity in the initial of the first name, such as beginning it much above or below the line, carrying a flourish from its last-written part to surround part or all of the other letters, etc.

Attention to the relative sizes and angles of its different parts is usually rewarded in such cases by discovering a number of particulars in which it differs from spurious imitations. However carefully their writers try to carry out the general design, these letters lack the ease and dash of the genuine letters, even if they are more symmetrical and better joined. Leaving such peculiarities aside to be examined in all their parts under a strong

magnifying glass or the compound microscope, it is always well to measure the height and breadth from easily recognized and constant features, and the slope (or angle with the base-line) of the straight parts of the letter if it have these. (In such letters as *E*, *O*, etc., this latter measurement is generally impossible.)

After the examination of the whole series of undisputed signatures, some well-marked feature on the first initial letter, or the next following, should be selected, the representative of which can be easily found on all of them, and from this initial point the distance to similar points in other letters, and especially to some similar point as near as possible to the end of the final letter, should be measured. The distance apart of some of the consecutive letters, and the breadth of the spaces between the letters or names of the consecutive words should then be measured. The more of these measurements, carefully taken, the greater will be the accuracy of the conclusions drawn from their averages. The more important features or elements will suggest themselves after some practice.

It has been the habit of the author to look carefully over the writings and decide upon the number of measurements of length, height, and angle to be taken; then to rule off on a sheet of paper a number of columns equal to that of the features selected, leaving a horizontal line for every specimen studied.

In this way the numbers corresponding to the same parts or features of twenty or thirty specimens fall into

vertical columns and can be readily added and their mean taken. It will also be found advantageous to keep together the measurements of horizontal distance, of height, and of angles, in order to avoid confusion.

After this has been done, and the means or averages placed at the foot of the columns, the specimen or specimens in dispute are carefully measured, and the results set under these averages, but leaving an intervening line for the insertion of the per cent. of difference between the successive pairs of values.

Selection of Points—It will often be found difficult to select the point from which to begin and that at which to end a measurement. Many names beginning with rounded letters, like *B*, *E*, *O*, etc., usually differ in breadth in different signatures by two or three units of the scale used, and the peculiar habit of writing it may make any letter difficult to start a measurement from. Wherever a flourish or other habit produces a crossing of one line by another, such crossing is generally a good point from which to start, more especially if it occur near the completion of the letter, because, however erratic the general appearance of a letter may be, its writer will insensibly seek to begin it and end it in the same way. But no general description will suffice to indicate in all cases where to select the points for measurement. A study of the largest number of undisputed specimens of writing will most probably suggest to one of some experience which are best, and if these fail, the investigator must have recourse to certain gen-

eral principles. For instance, it is safe to assume that the general line of writing is governed by the writer's habit after the initial letter is formed. In the case of a blank sheet without guide-lines even an experienced writer may make the first letter in a very different relation to the top and sides of the sheet from that which he naturally adopts when his guide-line is furnished, but after this first letter is made the following letters will preserve to it closely the normal relation. For this reason it will often be found advisable to commence the measurement with the second letter, and to carry the measurements only to the first part of the final letter, or to the letter next to the last, to avoid the frequent distortion of the latter part, due to preparations for the ending, which usually contains some peculiarity not found in the same final letter when written by the same writer in the body of a text.

Angles.—After all the characteristic distances between the selected letters have been measured, the angle or slope of the longer letters should be taken,—*i.e.*, the *b, d, f, g, h,* etc.

The advantage of this is that the slope of the letters, besides being determined by the natural structure of the arm of the writer, and his or her habit of employing a particular point of it for a pivot, is a constant not so easily appreciable by the eye, and deviated from even by expert forgers whose attention perhaps is more frequently fixed on imitating the forms of the letters than on their inclination. Of course, no general rule can be

laid down as to the usual slope in these long letters, but in such documents as the author has measured the great majority have shown the angles made by the long and straight letters with the actual or imaginary guide-line to be forty-five degrees to seventy degrees from the left to the right upward. Very few have a less angle with the guide-line than forty-five degrees, and though there are not infrequent cases of back-hand writing where the slope is from the upper left hand downward to the right, these and other slopes exceeding seventy degrees are, on the whole, more unusual.

Employment of Averages obtained.—A large number of linear and angular measurements of undisputed signatures having been taken, averages of all are obtained, and these averages should be compared with either the single word in dispute, or, if there be several of them, with each separately, and also with their average.

In the experience of the author a difference of fifteen per cent. between the two constitutes a ground for suspecting the genuineness of a disputed writing, if this amount is reached or exceeded in several of the features measured, *and* the writing may be assumed to be normal.

A difference of ten per cent. from the average in several of the linear measurements of two genuine words is not unusual, and five per cent. difference between the angles of the letters with the horizontal or base line is not inadmissible, but it is less common for an average of a number of genuine words to differ from the corresponding measurement of any normal genuine word by

as much as fifteen per cent., either in linear measurement or in angle, though individual signatures may do so from each other. Of course, there is always a possibility that the writer may have written the word or words under examination unusually large or small, for some good reason. In such cases the actual measurements of parts will differ very greatly from the corresponding averages obtained from genuine signatures, and the employment of ratios becomes of great value, because these are unaffected by such increase or decrease of size.

The results once obtained are tabulated and placed in columns in order that they may be compared, and conclusions drawn from such comparison.

In certain tables cited here as examples of the method of tabulating the results of an investigation of handwriting it was unnecessary to use the names in full. They have all appeared in judicial proceedings, and in all cases the verdict of the jury was in accordance with their indications.

Examples.—The old methods employed in the investigation of handwriting for the purpose of identifying the writer, are nowhere so fully and clearly developed as in Twisleton's book on the Junian letters, alluded to in the introduction.

A problem of this kind is better adapted for illustration in a treatise on methods than one of present interest, where prejudices may interfere with a calm discussion, or considerations foreign to impartial research may obscure the issue.

Mr. Chabot, the eminent English expert, whose investigation is the subject matter of Mr. Twisleton's book, sums up the results of his extensive and complete work as follows: 1. There are nine peculiarities of form, slope, size, and junction of small letters common to the writings of Francis and of Junius; 2. There are ten habits of dating, signing, punctuating, enlarging, and using capitals and dashes, etc., common to both writings.

Mr. Twisleton, in his very able comments on Chabot's work, asks if it is possible that these nine peculiarities and ten habits should exist in two writings by different hands?

The answer must be that it is extremely improbable, and yet none but the most superficial of all the characteristics of handwriting were considered by Mr. Chabot,—those which appeal to the eye. An immense amount of time and money have been expended to convince the reading public of the truth of his conclusion, and to put it in possession of accurate fac-similes of the writings of Sir Philip Francis and of Junius. This latter act of generosity has enabled the present writer to apply to the solution of this problem one of his own methods which deals with other than the visible peculiarities which a skilful penman might imitate. It will serve as a means of comparison between the strength of conviction which results from nineteen minor visible and superficial resemblances, and that which is based on but two instances of hidden organic structure. If it were seriously attempted here to decide the main question at issue, the

number of tests would have been increased. One of the advantages of this method of studying handwriting is that this can be done almost indefinitely.

The two methods stand to each other very much as the ancient and modern systems for classifying animals. The former was a minute description of the external form, and the color and other visible characteristics of the covering, whether bare skin, feathers, hair, or scales. The modern classification disregards all these accessories as a means of determining the true affinities of a specimen, and relies upon the parts unseen in the animal's life; the bony structure, the mutual relations of the parts thereof, and, to a lesser extent, the soft parts and organs of the animal. One reason for this latter mode of classification in zoology is the advantage of rendering possible comparisons between the extinct and living species. An analogous advantage in grammapheny is the detection of the same agent in writings widely separated in date, or made under greatly varying physical conditions.

It will be readily conceded that at least two factors are present in the performance of an act which is often repeated. One is the general similarity, and the other is the variation in some details which prevents any two acts or results from ever being exactly identical. These are analogous to the two important factors of the theory of Evolution, called, by Charles Darwin, hereditary transmission and accidental variation. In order to arrive at some approach to an ideal standard of similar recurrent actions, it is necessary to eliminate, so far as

possible, the accidental variations. The most obvious way to do this is to take the average or mean of the records of a number of such actions, for in this the influence of the accidental variations will have diminished or even disappeared, and only the essential parts of the act, or the results which portray the act, will remain. Applying this to handwriting, the first object in grammapheny should be to obtain as many as possible of the characteristics of a word which an individual was accustomed to write, as free as possible from the accidental variations which exist in each single example of it. This may be done automatically and graphically by composite photography, in a manner described at length in another place; or by separate measurements and comparisons. The first method has the advantage of taking note instantaneously and accurately of all visible features of the word; and the resulting composite will accentuate all characteristics which were often repeated, and suppress in a blur those which were accidental. The second method, or that of measurement, it is true, takes account of but an infinitesimal fraction of all the visible features of a word, and records each of these features as equal to so many units of a standard measure. It also obtains the averages of these values in the genuine writings and compares these averages with measurements of corresponding features from writings of which the authenticity is not established.

Each of these two methods has its advantages and its disadvantages. The advantage of the graphic method

is, as has just been said, that it omits from its result no visible feature of the thousands or millions which might be selected for examination. This is done accurately, instantaneously, automatically, and free from the personal error of an observer. But its disadvantage is that when the ideal word of the writer is thus obtained it is simply an image to the eye which expresses no relation to the writing with which it is to be compared, except that which the eye can appreciate; so that the real work of comparison must be begun by substituting this composite as the standard specimen of genuine writing. Moreover, the lines of the composite are necessarily thicker, and its angles and slopes are less sharply defined than those of an original word, and therefore more difficult to measure. Finally, it is expensive and often impossible to procure a properly made composite.

On the other hand, as an offset to the comparatively few component parts of the word which are obtained by the second method, one reads in the numbers representing the averages and measurements exact statements of fact and relation to the word with which it is to be compared. But a far greater advantage than this is the power of extracting from these numerical data the *relations* between the parts of a word or of a part to the whole word. The worst that can be said against it is that some of the features selected for measurement may not be the most essential; and if the number of genuine specimens of the word, from which averages of the features are calculated, be not sufficiently great, it might hap-

pen that too many corresponding features of the genuine words would show large divergences from those averages.

In spite of this theoretical weakness, however, the method has proven itself to be valuable in furnishing solutions to just such problems as that which Mr. Chabot undertook, and the manner of its application will here be shown.

The principle involved in the following study is simply that an individual accustomed to write a word will involuntarily preserve an approximation to uniformity in the mutual relations of all the parts or features of that word and not merely of a few such parts. Though he may never write the word twice of exactly the same length, and will even sometimes purposely shorten or lengthen it for special reasons, yet he cannot, without effort, avoid making approximately the same proportions of lengths of a part to the whole, and to other parts. Especially is this true of the heights of letters (preferably in the middle of the word) to the length of the whole word. The writer does this more accurately than the most expert imitator, because with him the mental model is present and the accommodation of the muscles to produce just so long a word for so great a height of letters, etc., is habitual.

For the first example of the application of the method just described I have selected the word "more," repeated thirty-six times each by Sir Philip Francis and Junius, and photolithographed in the first four columns of Plate G of Twisleton's book.

The length of the word and the height of the letter

Study of the Word "more," as written by Sir Philip Francis and Junius, by the Method of Measurements and Ratios. The Units are 0.0635 cm. (one-fortieth Inch).

Sir Philip Francis.			Per cent. of difference from standard ratio.	Junius.			Per cent. of difference from standard ratio.
A Length of word.	B Height of letter "r."	$\frac{B}{A}$ Ratio of length to height.		A′ Length of word.	B′ Height of letter "r."	$\frac{B'}{A'}$ Ratio of length to height.	
22.0	4.0	0.181	1	15.5	3.5	0.225	8
21.0	3.5	0.166	8	14.0	2.5	0.173	1
21.5	4.0	0.186	3	12.0	2.0	0.166	8
21.0	4.5	0 214	16	15.0	2.0	0.133	26
21.5	5.0	0.232	23	14.5	2.5	0.172	5
19.0	4.0	0.210	14	13.5	2.5	0.185	3
22.5	4.0	0.177	2	15.0	3.5	0.233	23
21.5	4.0	0.186	3	15.5	3.0	0.192	6
22.0	4.0	0.181	1	16.5	3.5	0.212	15
20.0	4.0	0.200	10	14.0	2.5	0.178	1
25.0	4.0	0.160	11	12.0	2.5	0.208	14
24.0	4.0	0.166	8	19.0	3.5	0.184	2
20.0	3.5	0.175	3	15.0	3.5	0.233	23
23.0	4.0	0.174	3	21.0	3.5	0.166	8
21.5	3.0	0.139	23	15.0	2.0	0.133	26
29.0	4.0	0.138	23	15.0	2.5	0.166	8
22.0	4.0	0.181	1	15.5	3.5	0.161	11
22.0	4.0	0.181	1	15.5	3.0	0.193	7
23.0	4.0	0.174	3	10.0	3.0	0.300	40
26.0	6.5	0.250	28	13.0	2.0	0.146	18
24.0	4.5	0.187	4	14.0	2.5	0.179	1
22.5	4.0	0.178	1	13.0	2.0	0.146	18
22.0	4.0	0.181	1	15.5	2.0	0.129	22
18.5	4.5	0.243	26	13.0	2.5	0.192	6
19.0	3.5	0.184	2	14.0	1.5	0.107	41
25.5	4.0	0.158	12	13.0	3.0	0.230	22
27.0	3.0	0.111	38	14.0	3.0	0.214	16
19.0	3.5	0.184	2	14.0	2.0	0.142	21
22.0	3.0	0.136	24	14.0	2.0	0.142	21
19.0	3.5	0.184	2	17.0	2.5	0.147	18
20.0	4.0	0.200	10	14.5	2.5	0.172	5
25.5	4.5	0.180	0	13.0	2.5	0.192	6
19.5	4.0	0.205	13	13.5	3.0	0.222	9
20.0	4.0	0.200	10	12.5	2.5	0.200	10
20.0	3.0	0.150	17	11.0	1.5	0.136	24
24.0	4.0	0.166	8	12.0	2.0	0.166	8
Sum . . 795.0	143.0	. . . . .	. . . .	514.5	93.5	. . . .	. . . . .
Average 22.06	3.94	0.180	. . . .	14.29	2.59	0.182	1

Difference of ratios $\frac{B}{A}$ and $\frac{B'}{A'}$, = 1 per cent.

Summary of Agreements and Differences of Ratios of Individual Words from Ratio of Means.

	Agreements Close.		Differences Wide.	
	Eight per cent. and under.	Over eight and under sixteen per cent.	Over fifteen and under twenty-three per cent.	Over twenty-three per cent.
Sir Philip Francis (thirty-six specimens)	19	8	2	7
Junius (thirty-six specimens)	16	5	8	7

"r" have been measured in each word, and averages of these measurements for each series of thirty-six examples obtained. The ratios of the averages of length to height in the two series are found to agree within one per cent. (!).

This ratio of the length to the height was then calculated for each of the seventy-two words under examination, and the per cent. of difference was noted between each result and the ratio of the averages of these two elements in Sir Philip Francis's writing, which were made the standards.

From a table embodying these results it appears that in Francis's own writing (from which the standard was evolved) nineteen, in Junius's sixteen, of these ratios differ by less than eight per cent. from the standard. In Francis's eight, in Junius's five, differ between eight and fifteen per cent.; in Francis's two and in Junius's eight differ between fifteen and twenty-three per cent.; and in

Francis's seven and in Junius's seven differ by over twenty-eight per cent.

The principle involved in this kind of examination is that the same hand, though never twice writing a given word of exactly the same size, and often greatly varying the dimensions, nevertheless unconsciously conforms more closely to uniformity in the relations of parts to each other than any imitator can; partly owing to the model which is before the genuine writer's mind, and partly to the habit of going through the motions which in the case of a signature becomes almost a reflex act. When the word is lengthened or shortened the heights of letters in that word will be correspondingly increased or diminished. This unconscious preservation of uniform proportion will pervade all parts of the word, or, more properly speaking, it is equally likely to pervade every part, whereas the effort of an imitator will infallibly result in making many minor parts fail to retain their usual relations to each other and to the whole word, while he successfully reproduces one or two.

A further exemplification of the method just explained, is taken from the same series of Francis-Junius letters. The subject of study in this case is the word "Woodfall," written in a letter by Sir Philip to Mackrabie, June 12, 1770; and by Junius, in a letter dated April 5, 1769.

These two writings of the name of Junius's publisher look as little as possible alike, and very probably would not be connected by the old methods of superficial comparison, but when they are each carefully measured and

their respective ratios of parts compared, the differences are found to be below those suggesting a different penman. One peculiarity of the results of this analysis is not easily explained: viz., that the percentage difference between four separate ratios of the Franciscan and Junian words is the same,—six per cent. It would seem to show that the peculiarities which Sir Philip adopted when writing under the pseudonym were maintained with quite extraordinary uniformity, as well as the peculiarities of his natural hand. It should be remembered that differences so small as six per cent. are negligible as errors of observation.

Study of the Word "Woodfall" in Writings of Sir Philip Francis and Junius.

Letters of Sir Philip Francis and Junius.	Length and Height.						Angle.		Ratio.			
	A	B	C	D	E	F	G	H	$\frac{A}{C}$	$\frac{A}{D}$	$\frac{A}{E}$	$\frac{A}{F}$
Sir Philip Francis to Mackrabie, June 12, 1770.	31	3	4	3.5	3.5	11	50°	50°	7.75	8.85	8.85	2.81
	Difference Per Cent. between Ratios.								6	6	6	6
No. 1, Junius to Woodfall, April 5, 1769.	16.5	1.5	2	1.75	1.75	5.5	70°	70°	8.25	9.42	9.42	3

The parts of the word measured were as follows: A, *W* to final *l*; B, distance between lower points of *W*; C, *d* to *f*; D, *f* to *a*; E, distance between the *l*s; F, height of *f*; G, angle of first stroke of *W*; H, angle of *f*.

The conclusion from the results of the last as well as from the preceding is that the same penman wrote the letters of Sir Philip Francis and of Junius.

Example 2. Employment of Angles only.—In the short table below are ten columns each bearing the record of the inclination in degrees with the horizontal of some part of a letter in a given signature.

The first line gives the averages of measurements in twenty different undisputed signatures.

The second line gives the measurements of similar parts of a disputed signature.

The third line gives the measurements of similar parts of a composite of all of the genuine.

TABLE I.

Degrees of Angle on the Horizontal Line.

Average of 20 signatures . .	46.4°	65.9°	48.06	30.42°	60.79°	52.25°	45.20°	55.65°	46.05°	45.55°
Disputed signature (A) . . .	55°	70°	. . .	30°	60°	50°	45°	55°	45°	45°
Composite . . .	50°	68°	50°	32°	60°	50°	45°	55°	45°	45°

The question at issue was whether or not the signature was genuine, and twenty undisputed signatures were obtained from which to make a basis of comparison. In this case, for particular reasons, only angular measurements were taken.[1] These gave the average noted at the foot of the page. The same elements of the disputed signature were obtained and written under these averages. The agreement was so close as to justify the belief that the disputed signature was genuine.

A composite photograph was then made of the twenty

[1] It need hardly be said that where possible other than measurements of angles should be employed.

signatures, and the elements of the composite were also measured. The agreement of these with those of the disputed signature was extraordinary, and tends to show the value of the method of study by composite photography.

Ratios of Parts of a Letter.—It is not only in the ratios of parts of words or sentences that opportunity is afforded to identify the writer by his unconscious tendency to preserve relations which are hidden from the eye, but even in a single letter. As an example of this, a study was made of the relative lengths of the tails of a number of ys from the bottom of the loop to the junction with the first part of that letter, and of the lengths from the bottom of the loop to the crossing of the down stroke by the up stroke of the tail. The annexed table

	A	B
Letter (Writer known).	Length of tail of *y*.	Length from bottom of tail of *y* to crossing of loop.
Page I., line 12, word 6, letter 1	15.5	11.0
Page I., line 7, word 2, letter 4	17.0	9.0
Page I., line 7, word 3, letter 1	16.0	9.0
Page I., line 7, word 3, letter 9	21.0	11.0
Page I., line 8, word 5, letter 2	20.5	15.5
Page I., line 15, word 2, letter 5	15.5	8.5
Sum of above	105.5	64.0
Divided by 6 = average	17.58	10.66
Ratio A to B (17.58 = 100)	100.	60.9 (say 61)
Ratio A to B (40.5 = 100)	100.	62.2 (say 62)
Divided by 5 = average	40.5	25.2
Sum of below	262.5	126.0
Anonymous Letter.		
Page I., line 4, word 4, letter 1	38.0	28.0
Page I., line 6, word 2, letter 1	42.0	21.5
Page I., line 10, word 1, letter 1	41.5	26.0
Page II., line 9, word 5, letter 1	40.0	26.5
Page III., line 2, word 4, letter 1	41.0	24.0

will show the results. The first six lines give the page, line, word, and letter of the specimen from a known writing which was measured. The last five lines give similar data for the specimens taken from an anonymous letter. In the latter case the additions, averages, etc., are added and recorded upward, so that the results may be brought into comparison with the similar results of the first table which are brought down. The agreement within, practically, one per cent. is strong evidence of the identity of the writer of both letters.

This difference of ratio is very small, and far within the error of observation.

This test would tend to show that the two letters were by one hand.

CHAPTER XIII.

"GUIDED HANDS."

Character of such Writing.—Cases frequently occur where it is admitted that the hand of the person who wrote a signature was guided by the hand of some one else.

The writing produced by two hands conjointly is usually erratic, and, at first sight, hard to connect with the handwriting of any one person. In appearance it changes abruptly from very high or very wide to very low or very narrow letters.

Theory.—This is to be explained by the non-agreement in phase of the impulses due to each of the two

writers. If both are endeavoring at the same moment to write a given stroke in the same direction, the length of that stroke will be measured by the sum of the impulses given by the two writers. If they act in opposition to one another, one seeking to make a down stroke while the other is trying to make an up stroke, the result will be a line equal to the difference between the stronger and the weaker force.

As these coincidences and oppositions occur at irregular but not infrequent intervals, like the interference and amplification phases of light- and sound-waves, the result traced on the paper might be expected in advance to be, as it is, a distorted writing where maxima and minima of effect are connected together by longer or shorter lines of ordinary writing.

The tabular statement by numerical average of one case will be shown and more specifically explained elsewhere.

Manner of Guiding.—The usual and perhaps only legitimate reason for guiding a hand executing a legal instrument is the feebleness or illness of its owner.

When such assistance is required it is usually given by passing the arm around the body of the invalid or otherwise incapacitated writer, and supporting the writing hand while the necessary characters are being made.

Both participants in this action are looking at the writing, and both are thinking of the next letter which must be written, and of the motion of the pen necessary to produce it. Unless the executing hand were absolutely lifeless or entirely devoid of power, it would be

impossible for it not to influence the guiding and presumably stronger hand; for the least force exerted cannot fail to deflect a hand, however strong, in an unnatural and cramped position. Nor can the hand of the guider fail to add its contribution to the joint effort, however much the brain which controls may strive to render it entirely passive. Both minds are busy with the same act, and insensibly both hands will write the same letter with the results just described.

Analysis of Guided Writing.—Can the characteristics of each hand be separated from those of the other and the relative amount of the two contributions to the joint signature be stated?

From the comparatively small number of experiments made by the author in this direction it would be hazardous to answer it by an unqualified affirmative, but it may be said that some of the characteristics of each hand can usually be made apparent by the system of measurement, and the indications seem to point to the probability of an increase in the number of characteristics elicited in proportion to that of the observations made. If the significance of every part of every stroke could be properly interpreted, a complete separation of characteristics might be effected, but this would require an indefinitely large number of observations and a quite unattainable skill in explaining them.

Example.—Table II. contains the data of the study of a disputed signature.

Columns one to thirteen inclusive refer to measure-

TABLE II.

DOCUMENTS.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	Length *H*—*a*.	Length *a*—*t*.	Length *t*—*y*.	Length *y*—*S*.	Length *S*—*h*.	Length *h*—*d*.	Length *H*—*d*.	Height of *H*.	Height of *H* above line.	Average height above line letters of first name.	Height of *y*.	Height of *S*.	Height of *h*.	Angle of last down stroke of *y*. α	Angle of last up stroke of *y*. β	Angle of down stroke of *a*. γ	Angle of second up stroke of *y*. δ	Angle of first up stroke of *S*. ϵ	Angle of middle of first down stroke of *S*. ζ
	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
Name, 1st line	4	11	7	4	2	14	44	5.5	1	0.7	4.5	4	4.5	68	20	39	9	30	65
Signature at end	3	14	9	4	2	14	48	4.5	1	0.6	4	4.5	5	70	30	30	3	40	75
Average	3.5	12.5	8.5	4	2	14	46	5	1	0.65	4.25	4.25	4.75	69	25	31.5	6	35	70
A	5	14	7	7	2	13	49	7	1	*a* touches 0.5	5.5	7	6	60	30	40	10	25	50
B	6.5	17	7	8	2	12.5	53.5	*6	0	0	5	6	6	60	12	32	8	20	50
C	6	18	8.5	6	3.5	11	52.5	7.5	0.2	0	6	7	7	50	12	30	10	20	40
D	5	15	12	6	3	18	59	8	1	1	†9.5	7	7	60	20	50	30	32	58
E	5	13	9	6	3	15	‡39.5	7 (below line.)	0	0	*y* omitted.	7	6.5	50	20	50	No *y*.	32	60
F	4.5	16	9	7	3	15	54.5	9	1	1	5.5	6	6	50	25	40	10	30	43
G	3	17.5	9	9	3	18	60	7	0	0	5	6	7	50	20	38	20	25	60
H	7	13	10	9.5	3	17	58	6.5 (below line.)	1 (below line.)	Very small.	6	6.5	5.5	50	10	50	5 Too short.	30	50
I	5.5	. . .	8	5.5	3	14	. . .	6.5 (below line.)	0	Very small.	5.5	5	6	50	10	10	Too short to measure.	20	60
J	6	. . .	8.5	6.5	3	15.5	. . .	6 (1.5 below line.)	1	0.5 (below line.)	4.5	5	4.5	50	10	10	Too short to measure.	20	48
K	5	15.5	7	7	3.5	11	51.5	7	0.5	. . . .	6.5	6	5.5	50	10	40	10	20	50
Average	5.32	15.41	8.61	7.04	2.90	11.81	53.05	7.06	0.15	0.31	5.90	6.22	6.09	52.72	15.45	35.45	12.87	21.90	51.72

* Lower stroke of *H* below line 0.5 mm.

† Tail of *y* below line.

‡ The final *r* in last name omitted.

ments between certain selected parts of letters, heights of letters, etc.

Columns fourteen to nineteen inclusive include angular measurements of parts of letters.

The first three horizontal lines represent a name at the commencement of a will, the same name as a signature, and an average of their combined measurements. The following eleven horizontal lines contain corresponding measurements of as many undisputed signatures, with their averages in the lowest line. The disagreement, in many characteristics, between the measurements of the authentic signatures and the measurement of the signature at the end of the document, and their close agreement in others, strikes the eye at once. The various grades of approach from close approximation or identity of measurement to wide divergence would lead one to suspect the cause to have been periodical perturbation of a normal hand, and this view is strengthened when one compares the numbers representing the successive measurements of the elements of the disputed signature with the corresponding numbers of the undisputed series.

In columns three, six, and sixteen the measurements of the signature agree fairly well with the averages, but in seventeen, eighteen, and nineteen (all angles) the signature shows the widest discrepancies when compared with the averages of the larger series.

There are too many approximations between the two to render it probable that the signature was made entirely independently of the hand which made the lower

PLATE XIV.

I. Edwin S. Barley

II. Group.
a Edwin S. Barley
b Edwin S. Barley
c Edwin S. Barley

III. Group.
a Edwin S. Barley
b Edwin S. Barley
c Edwin S. Barley

IV. Group.
a Edwin S. Barley
b Edwin S. Barley
c Edwin S. Barley

V. Group.
a Edwin S. Barley
b Edwin S. Barley
c Edwin S. Barley

VI. Group.
a Edwin S. Barley
b Edwin S. Barley
c Edwin S. Barley

VII. Group.
a Edwin S. Barley
b Edwin S. Barley
c Edwin S. Barley

VIII. Edwin S. Barley

Eight experiments representing progressive influence of one hand upon the other in guided handwriting.

series, and yet the wide divergences in a large number of the components investigated show that another force was modifying the first. It had the appearance of a guided hand, and this appearance was further confirmed when analysis showed that several elements in the disputed signature differed radically from about one hundred and seventy-five instances of the same elements in the genuine writing of the hand which was suspected of having forged it, while agreeing very closely with those in the undisputed signatures of the person whose name was attached to the will. This method supported the view (which was afterwards corroborated by direct testimony) that the suspected signature was produced by the hand of the person whose name it indicated, guided by the hand suspected of forging it.

These tables are introduced for the purpose of showing the system by means of which the separate observations are recorded, combined, and employed.

Plate XIV. and Tables III. and IV. illustrate an experiment in this direction. The supposititious name "Edwin S. Barley" was selected, and two persons, A and B, practised writing it for some time, in order to attain some facility, at least remotely resembling that which every one has in writing his own name.

In addition to this, the name was chosen to agree very nearly with the real name of the person whose hand was guided (Edwin S. Bailey), so that the habits he had acquired in writing his own would be transferred largely to the fictitious signature.

TABLE III.

Measurements of the Writing of a Guided Hand.

	E—d.	*d—n*	*n—S.*	*S—B.*	*B—a.*	*a—y.*	*E—y.*	Height. *E.*	Height. *S.*	Height. *B.*	Height. *d.*	Height. *l.*	Angle of *d.*	Angle of *S.* β	Angle of *S.* γ	Angle of *B.*	Angle of *l.*
	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Deg.	Deg.	Deg.	Deg.	Deg.
I.	5.5	19	21	13	6.5	28.5	93	9.5	8	8.5	6	6	40	30	50	48	30
II. *a*	9	22	21.5	10	8	28.5	101.5	9.5	8	10.5	5	6	40	20	50	45	25
II. *b*	10.5	28	23.5	8.5	8.5	28	100.5	8	7.5	9	4	4.5	30	12	50	40	30
II. *c*	7	13.5	25.5	9	7	28	101	6.5	6.5	10.5	3.5	5.5	50	15	50	40	30
II. Average .	8.83	21.16	23.5	9.16	7.83	28.23	101	8	7.33	10	4.6	5.33	40	15.66	50	41.66	28.33
III. *a*	10	27	22	11	7.5	25	103	9.5	6.5	9.5	5	5.5	40	23	50	50	30
III. *b*	8	24	24	11	6.5	31	105	7	6.5	7.5	4	3.5	50	20	50	42	25
III. *c*	7	24	23.5	10	10	30	105.5	6.5	6.5	9	5	4.5	58	15	40	40	25
III. Average .	8.33	25	23.16	10.33	8	28.66	104.5	7.66	6.5	8.66	4.66	4.5	49.33	19.33	46.66	44	26.66
IV. *a*	7	26	21.5	10.5	9	31.5	101.5	7.5	6.5	8	5.5	5.5	58	20	50	48	27
IV. *b*	7	26	21.5	10.5	7	28	99	7	6.5	7	5	4.5	58	15	68	45	30
IV. *c*	8	25.5	21.5	10	8	33.5	104.5	7.5	7	7	5	6	48	20	60	30	30
IV. Average .	7.33	25.83	21.5	10.33	8	31	101.66	7.33	6.66	7.33	5.16	5.33	54.46	11.66	62.66	41	29
V. *a*	7	22.5	19	10	7	26.5	96	8.5	8	6.5	7.5	5	70	20	70	50	25
V. *b*	10	23	18.5	10.5	5.5	28	96	8	7.5	8	6	6.5	50	20	70	50	40
V. *c*	8.5	25	20	10.5	8.5	29	100.5	7	8	9.5	6	4	40	20	70	50	40
V. Average .	8.5	23.5	19.16	10.33	7	27.83	97.5	7.83	7.83	8	6.5	5.16	53.33	20	70	50	35
VI. *a*	9	28	21	13	8	33	112	10.5	10.5	13	8	7	60	23	70	55	35
VI. *b*	10	21	18.5	13.5	7	27.5	97.5	9.5	9	12	8.5	5	45	25	65	40	30
VI. *c*	8.5	25	22	16	5.5	28	104	9.5	9	12	5.5	6	50	30	60	50	40
VI. Average .	9.16	24.66	20.5	14.16	6.83	29.5	103.16	9.83	9.5	12.33	7.33	6	51.33	26	65	48.33	35
VII. *a*	5.5	16.5	16	10.5	5.5	24.5	79	6.0	8.5	8	6	7.5	60	10	60	70	50
VII. *b*	7	20.5	11.5	13	5.5	21	79	8.5	8.5	8	6	8.5	68	10	58	70	55
VII. *c*	3.5	19.5	11.5	12.5	6.5	19.5	71.5	5.5	6.5	7	5	5.5	70	3	58	65	38
VII. Average	5.33	18.83	13.0	12	5.83	21.66	76.5	6.66	7.83	7.66	5.66	7.16	66	7.66	58.66	68.33	47.36
VIII.	6	15.5	17.5	12.5	4.5	21.5	78	7.5	11.5	11	5.5	8.5	50	35	50	50	40

TABLE IV.

Averages of 320 Observed Measurements of the Writing of a Guided Hand, from Table III.

	E—d.	*d—n.*	*n—S.*	*S—B.*	*B—a.*	*a—y.*	*E—y.*	Height. *E.*	Height. *S.*	Height. *B.*	Height. *d.*	Height. *l.*	Angle of *d*, long stroke.	Angle of *S*, up stroke.	Angle of *S*, down stroke.	Angle of *B*, main stem.	Angle of *l*, up stroke.
	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Mm.	Deg.	Deg.	Deg.	Deg.	Deg.
I.	5.5	19	21	13	6.5	28.5	93	9.5	8	8.5	6	6	40	30	50	48	30
II.	8.83	21.6	23.5	9.16	7.83	28.23	101	8	7.33	10	4.6	5.33	40	15.66	50	41.66	28.33
III.	8.33	25	23.16	10.33	8	28.66	104.5	7.66	6.50	8.66	4.66	4.5	49.33	19.33	46.66	44	26.66
IV.	7.33	25.83	21.50	10.33	8	31	101.66	7.33	6.66	7.33	5.16	5.33	54.66	11.66	62.66	41	29
V.	8.5	23.5	19.16	10.33	7	27.83	97.5	7.83	7.83	8	6.5	5.16	53.33	20	70	50	35
VI.	9.16	24.66	20.5	14.16	6.83	29.5	103.16	9.83	9.5	12.33	7.33	6	51.33	26	65	48.33	35
VII.	5.33	18.83	13	12	5.83	21.66	76.5	6.66	7.83	7.66	5.66	7.16	66	7.66	58.66	68.33	47.36
VIII.	6	15.5	17.5	12.5	4.5	21.5	78	7.5	11.5	11	5.5	8.5	50	35	50	50	40

In Experiment I., Plate XIV., the name was written freely by A. In the group of three experiments, II., *a*, *b*, and *c*, B supported the elbow of A while the latter wrote the name; both A and B, however, in this, as in all but the first and last experiments, together kept their attention fixed upon the writing.

In the group of three experiments, III., *a*, *b*, and *c*, the middle of the forearm of A was grasped by B.

In the Group IV., *a*, *b*, and *c*, the forearm was grasped and supported immediately behind the wrist.

In the Group V., *a*, *b*, and *c*, the wrist itself was grasped and supported, and its motion largely hindered.

In the Group VI., *a*, *b*, and *c*, the hand itself was tightly grasped, the wrist motion entirely prevented, and only the fingers and the arm left free to move.

In VII., *a*, *b*, and *c*, the hand and fingers were tightly held and free motion only allowed to the arm.

In VIII., B wrote the name without assistance or interference from A.

The signature was then examined, and seventeen features selected for measurement, which are indicated at the heads of the seventeen columns ruled on the paper.

The first seven columns refer to horizontal distances in millimeters between certain parts of letters. The succeeding five columns give the heights of as many letters selected from the rest, because it was thought that they would give more significant indications as to character.

The last five data refer to angles with the horizontal,

or the inclinations of the letters to the horizontal line on which they were written.

To prevent the error which would be likely to result from considering but one series of measurements for each of the seven cases just described, all but the first and last were repeated three times, and the averages of these triple measurements were taken as single observations and compared with each other and with the single signatures at the commencement and the close.

The resulting figures are complicated, but in general they show the greatest divergences from the type furnished by each of the experimenters in the middle spaces III., IV., V., and VI., or where the motions of both A and B were least restricted; and the least divergence in the spaces nearest to the type signatures.

Summary.—If the average of Experiment VII. (Table III.) be compared in numerical results with that of the free-hand Experiment VIII., it will be seen that about half of the results differ by less than fifteen per cent.

To be more accurate, they are as follows, counting the seventeen columns from left to right: 0.11, 0.17, 0.33, 0.04, 0.22, 0.006, 0.019, 0.011, 0.31, 0.30, 0.002, 0.015, 0.32, 0.78, 0.14, 0.27, 0.15. Eight out of the seventeen results differ by fifteen per cent., or less, whereas the results in the middle space III., IV., and V. differ in almost every case by much more than fifteen per cent., which has been arbitrarily assumed as the maximum variation to be generally allowed between any genuine signature and the average of a number of such.

Table IV. gives only the averages mentioned on Table III., omitting the separate measurements for the purpose of obtaining greater simplicity.

The greatest differences between Series VII. and VIII. are found in the angles representing slopes of the letters or inclinations to a horizontal line.

This is an additional instance of the value of this element (angle) in determining normal signatures.

Evidences of the Action of Two Hands in Joint Signature Marks.—If it be conceded that the effect of a given individual's will on that individual's mechanism of bones, muscles, nerves, etc., with which it has been associated in all acts of the possessor of both, results in the production of a script characteristic of that individual and of no other, it ought to follow that whatever be the pattern traced, whether a simple cross or a more complex series of conventional signs as in handwriting, it should contain the characteristics of the writer. In the case of a simple cross, these characteristics are much more difficult to discover than in that of ordinary writing or name-signing, but that they exist no one will deny who has taken into consideration the invariable tendency of man to contract habits in the performance of all acts which he repeats during a long period, and the growth

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NOTE.—Whether or not it be considered established that with care the elements of each handwriting can be proven in the guided signature, it is premature to affirm, as has been done in the local press, that "it is impossible for a person holding another's hand to infuse the character of the guider's hand into the writing."

of a habit from constantly taking the easiest method under existing conditions to accomplish what the will has commanded.

The fact that simple marks, made by persons ignorant of the art of writing or deprived of some organ or faculty possessed by the majority of their race, contain characteristics of the individuals who make them, is a logical sequence of the principles of grammapheny, and is susceptible of actual demonstration.

It is not the object here to treat of marks of this kind, but of those which are made by one person while another touches the penholder.

If great difficulties are encountered in dealing with ordinary writing, the difficulties in those of this kind are vastly greater and might well be considered insurmountable in so far as the problem involves the establishment of individual character from the traces of *resistance* to free pen movement observable in the joint mark.

The author speaks thus cautiously of the possibility of establishing the characteristics of one person from the traces of his interference with the free work of the actual holder of the pen—a problem, comparing the very small to the very great, analogous to the determination of the orbit and mass of an unknown planet from the effect of the latter on the movements of a known planet—because it is not possible to state how far legitimate investigation may be extended in the future by new devices and larger knowledge.

For the present he leaves this question untouched,

admitting that the chances seem against its ever being successfully solved, and addresses himself to the less complex question, "Can a mark made by one person while another is touching the penholder, be distinguished from a mark made freely and without external hinderance?"

Without theorizing, the subject can best be introduced by the statement of an actual investigation of marks which were made by a certain man while the penholder was touched by a blind woman.

The simple question was whether or not the marks attached to certain documents were made while the hands of two persons touched the same penholder.

By a cursory examination of the signature marks of some documents (of which the genuineness was disputed) with the signature marks admitted as genuine joint marks, a notable difference was observable. Whereas the former appeared well formed and shaded, and gave evidence of having proceeded from a hand skilled in the use of the pen, the latter were ill formed and ragged, neither symmetrical nor indicating the free movement of an experienced writer. The lines of the admitted signature marks were thin, and, especially the cross stroke (which was drawn from the upper left hand to the lower right hand), longer than the similar lines in the disputed signatures. But this superficial observation, while plainly indicating differences between the disputed and undisputed signatures, failed to establish their respective degrees of importance.

Before further study an examination was made of a list of twenty-odd names, among which was what was claimed to be an unauthorized and fraudulent signature-cross, and the latter was correctly identified with the writing of one of the names. The inclination of the lines and the spread of the pen-nibs corresponded so closely in the two cases that the careful measurements, which were immediately undertaken, were not needed to reveal the identity of the writers. This preliminary conclusion having been corroborated, a meeting with the persons who made the joint marks was arranged in order that their method of proceeding might be witnessed.

As there was a difference of statement between the two as to this method, specimens were taken under the conditions described by each.

The blind woman insisted that she grasped the top of the pen firmly. The guider of the pen maintained that his collaborator merely touched the top of the pen lightly while he wrote.

Joint marks were made by the two persons under observation, and were carefully measured and tabulated. Similar measurements were made of other admitted and disputed signature marks and similarly tabulated.

The measurements were divided into those of length and of angles, with scrutiny of the manner in which each stroke began and ended. The bearing of this latter feature upon the question of single or joint production was obvious, because with a foreign hand touching the penholder ever so lightly those movements which de-

pended upon the exercise or release of slight pressure could be produced only in a very imperfect manner.

It may be worth while to call attention to the method of utilizing the results of such tables as are here given, which seems to be important in proportion to the diversity and complexity of the factors which enter into them. The extraction of information from tables of statistics is frequently more difficult than the procuring of the statistics themselves. Let any one attempt to master, say, the significance as life insurance tables of the necrological reports of the cities and of the country at large, and he will appreciate the value of the art of Mrs. Glass after the hare is caught.

In general, the effect of minor components of composite forces are more clearly distinguished when the ratios of parts to each other and to the whole are considered. It is true that this method of presentation is open to the objection that it magnifies very small differences, but on the other hand it clearly distinguishes cases which have resulted from closely similar conditions. The most important information is obtained from a table representing the ratio to each other of columns in the original table, and the percentages of difference between measurements of objects whose origin is unknown or in doubt from those of similar objects whose origin is known. It is in this way that the full force of effects produced, as in this case, by the resistance of a hand touching a moving penholder may be made manifest, as the tables showed.

When this work had been done, further experiments in joint signature marks by various persons were undertaken, in order that the conditions peculiar to the above case might be replaced by generalizations useful in a wider field of inquiry.

With this view over three thousand five hundred marks were produced and examined, and the table which follows gives the percentages of the occurrence of various features in the free and in the joint marks respectively. The varying per cent. of exceptions in the results indicate different degrees of uniformity in the occurrence or absence of a given characteristic in a mark. Obviously, any feature to which there are but few exceptions in the three thousand five hundred experiments is of importance. The only feature discovered in these observations to which there was no exception was the existence of ragged margins in some part, and usually throughout the greater part, of a joint mark. When a mark is entirely free from such an appearance, therefore, it may be assumed, with a strong degree of probability, that it has not been subjected to the influence, however slight, of more than one hand.

In the following summary, the letters R. U. mean right upper, and L. D. mean left downward. R. U. L. D. means the stroke made from right to left and from above downward. L. U. R. D. means the stroke from left to right and from above downward. Proceeding from the right upper side in the direction of the sun or of the hands of a watch, the four quadrants are

designated by R. U., R. D., L. D., and L. U., respectively.

SUMMARY OF NOTES OF THE ABOVE CASE.

A UNDISPUTED JOINT MARKS.	B DISPUTED.
1. R. U. L. D. not convex to R. D.	1. R. U. L. D. convex to R. D.
2. Lines do not broaden in the direction in which drawn.	2. Lines broaden in the direction in which drawn.
3. One, and usually both, of the margins of the lines are crooked and irregular : one continuously so.	3. One, and usually both, margins straight. Crookedness not continuous on either margin.
4. In all genuine cases examined R. U. L. D. was shorter than L. U. R. D.	4. In sixty-six per cent. of cases examined R. U. L. D. was longer than L. U. R. D.

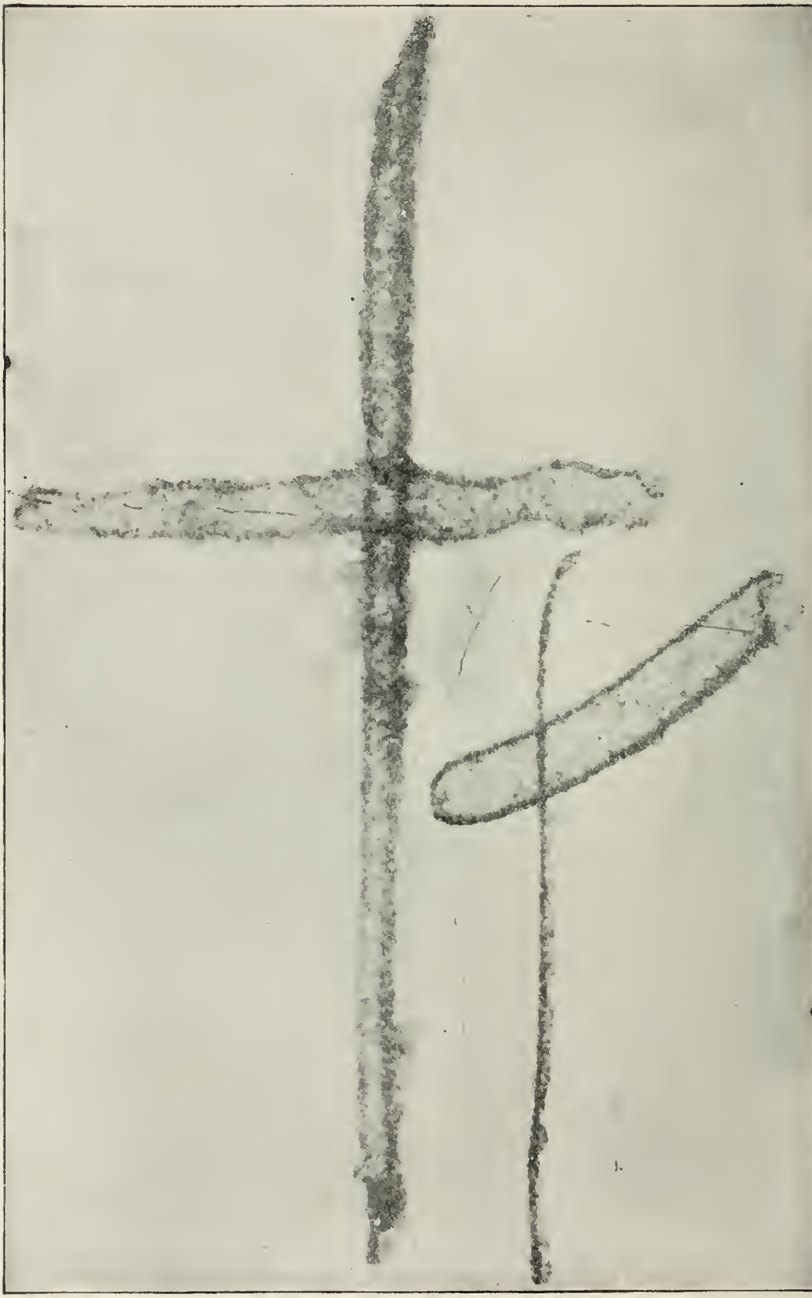
In three thousand five hundred independent examinations of experimental marks made either by one individual or by the joint efforts of various couples, there were found to be ten per cent. of exceptions to A 1, two per cent. of exceptions to A 2, but no exceptions to A 3.

A4 varied so much with the writing habits of different individuals that it is not regarded as of sufficient value to serve as a basis of discrimination.

It should be noticed that the usual absence of strokes convex to R. D. would naturally follow from the situation of the point of resistance when the pen is held in the position which some writing-masters call "natural," or slanting downward from left to right and pointing over the right shoulder.

In this position, to make a stroke R. U. L. D. convex to R. D. would require that the weight, added by contact of

PLATE XV.



1 2

1, Larger cross containing evidence of the touching by a second hand of the penholder used by the writing hand.

2, Smaller cross in which no evidence of the action of two hands appears.

the second hand, should be lifted, because in the act of drawing such a line the penholder must be changed to a more erect position, and the distance between the plane of the paper and that parallel to it, in which the top of the penholder lies, would be increased. In drawing the line concave to R. D. this distance would be diminished, and there would be no resistance to overcome.

The illustration on Plate XV. is fairly typical of the respective characters of joint pen marks made while two hands touch the penholder (as in the larger cross) and marks made freely by a single hand (in the smaller cross).

Both have been selected from the specimens of handwriting examined in the case above referred to. It should be borne in mind that the positions of these two crosses relatively to the horizontal guide line are not indicated here, the two crosses having been arranged in such a way as to be included on a single plate. The angle made by each stroke of a cross with the horizontal guide line is of considerable importance in assisting one to ascertain the identity of the writer, because the directions of these lines are governed by the writer's physical structure and peculiarities of will and muscular power; which, together with the original model in the writer's mind, produce the result which habit makes permanent. The crosses examined showed clearly the difference between marks made by the joint action of two hands and those by a single unhampered hand.

All the lines are considerably blurred owing to the

uneven absorption of the ink by the adjacent parts of the paper and also to the fact that the crosses were too hastily blotted after having been drawn, and the photograph magnifies these defects. For this reason the long lines in the plate are not sufficiently distinct to enable one to form an accurate judgment as to the crookedness of their lateral margins. It will, however, be conceded that of the four marginal edges, those of the broader line in the large cross are much more irregular than those of the broader line in the smaller cross.

PART III.

PLASSOPHENY.

CHAPTER XIV.

KINDS OF FORGERIES.

A FORGERY consists either in erasing from a document certain marks which existed upon it, or in adding others not there originally, or in both operations, of which the first mentioned is necessarily antecedent to the last; as where one character or series of characters is substituted for another.

The removal of characters from a paper is effected either by erasure (seldom by pasting some opaque object over the characters, painting over them, or affixing a seal, wafer, etc., to the spot where they existed), or by the use of chemical agents with the object of dissolving the writing-fluid and affecting the underlying paper or parchment as little as possible.

The essential idea in a forgery is that it gives a false impression either (*a*) to the reader, by the information it conveys, or (*b*) to the general observer as to its origin or relation to other things. The forgery, if falling under the first of these divisions, may be accomplished either

(1) by an erasure from or addition to an original record, whereby its original meaning is changed, or (2) by both methods together. In the second category belong those frauds relating to authorship and age which have been frequent from the earliest history of written records.

Plassopheny is chiefly concerned with the first class: the suppression of a "not," thus giving an affirmative instead of an intended negative; or the addition of a cipher changing 120 to 1200, are types of this class of falsifications.

The second class comprises the interpolation of chapters, verses, sentences, or words into the manuscripts of authors, as Eusebius is charged with garbling the history of Josephus, and many anonymous poetasters have endeavored to deceive the literary world by producing alleged newly discovered poems, or fragments of distinguished authors. This latter kind of falsification was so prevalent in the middle ages that Erasmus complained he had not a single copy of a manuscript entirely free from such frauds.[1] In general, the detection of this kind of forgery falls within the province of literature, and is accomplished by the application of literary tests which are outside of the province of bibliotics; and though, if the original manuscript be accessible together with unquestioned writing of the author whose name it bears, the study of the document itself might furnish the best evidence as to its authenticity, yet inasmuch as the scrive-

[1] Itasse. "Le faux devant l'histoire," etc. Paris, Delagrave, 1898.

ner in past ages was seldom the author, this study is less important than it otherwise would be.

A 1.—As to the first class, or the forgeries of erasure and addition, they are accomplished in many different ways.

Erasures.—In the days when writing was mainly undertaken on skins of goats and lambs, the most obvious method of removing a traced character was by scraping with a knife and with pumice or other hard powder. Instead of this, however, simple chemical solvents, such as water and milk of lime were used; depending upon the nature of the writing-fluid.

In modern documents the process is much the same. The forger has to contend against the difficulties of removing the upper surface, and therefore the sizing of the writing-paper, and usually attempts to replace it by means described elsewhere.

Clumsy attempts at concealment of parts of a written record by pasting over it a fragment of paper, or a wafer or seal, or covering it with ink, are not unknown, but are easily detected.

A 2.—The methods employed to add to the document something which was not there before, are various, and their number is constantly increasing. Some of them are: (1) The simple writing of the words required, in a hand as nearly as possible like the rest of the document, either in an available blank space or as an interlineation, or on a spot where other characters have been erased and the surface has been treated with some substance to act as a substitute for the sizing removed. (2) By tracing

the needed words from some genuine writing and transferring them by carbon paper or otherwise to the sheet, and inking them over with a pen. (3) By tracing the words from some genuine writing by superposing the new document over them and passing a strong light through both sheets. (4) By cutting out the letters from a genuine document and rearranging them to form the desired words, photographing these new words, and transferring them by some of the above methods to the sheet. (5) Removing the upper surface of a genuine letter or letters, by the "graphotype" process, and transferring it bodily to the place desired.[1] This is an entirely new and very dangerous means of forgery, but is adapted rather to the transfer of long sentences than of detached parts of words. Combined with the process mentioned in 4, however, it would seem to offer the most perfect means of forgery with the least chance of detection yet devised. As the process is the recent invention of a Parisian chemist, and is not generally known, there have not yet been instances of its employment noted in the courts.

In the supplement to *La Science Française* of December 3, 1897, a very interesting example of the system mentioned in 4 is given. M. Emile Gautier, its editor,

[1] Its effect is to secure a thin slice parallel to the paper of the actual writing, so that neither tests of its individual character, nor of the chemical character of the ink would demonstrate the fraud. Fortunately there exist other means of detecting such forgeries if the attention be alert.

writes to M. Obalski a short note asking him to procure from the expert photographers the details of the new methods of décalque, macquillage, etc. Out of this very note words and letters are cut and subsequently pasted together to form an excellent imitation of the running hand of the writer. The new sentences which are constructed are humorously uncomplimentary to the original author of the note. This new note is then photographed as an original letter, the outlines of the patches being obliterated on the negative. Prints from negatives of this kind are made on ordinary writing-paper and the illusion is complete, unless unusually close scrutiny be given to the whole document.

CHAPTER XV.

EVIDENCES OF TAMPERING.

Erasures.—If the erasure be effected by scratching or rubbing, this removes also the surface of the paper, which consists of some sort of "size" or paste with resin soap, which is pressed into the upper pores to give the paper a smooth appearance, and to prevent the writing-fluid from "running" or entering the pores and blurring the edges of the lines.

If the paper were left as it exists when the scratching or rubbing is completed, it would be very easy to see that it had been tampered with, for not only would the

parts thus abraded show the running of any fluid which was subsequently laid upon them, but the surface would appear rough to the eye in comparison with adjacent parts of the paper, and the place would appear thinner by transmitted light. Even to the touch the surface would reveal differences from the ordinary condition of other parts of the paper.

But the forger usually endeavors to overcome these difficulties by applying to the scratched area sandarach, resin, alum, paste, or two or three of these together, the effect being to prevent an unusually large flow of ink from the pen and its abnormal absorption by the paper.

The paper should be placed between the observer and a strong light, by which means, either with or without a magnifying-glass, a distinct increase in the brightness of the suspected area may be noticed, indicating a thinning, and even traces of letters, or marks which have escaped the erasing-tool, may be seen.

A close scrutiny may show places where the surface has been partially torn, and the fibres of the paper united together into little knobs, and almost invariably a magnifying-glass will clearly show the disturbance of the superficial fibres, as compared with other and normal parts of the paper. If the latter be tinted, the change of appearance may extend to color. The color of the paper should always be attentively observed.

Washing with Chemical Reagents.—A change of color over the part which is the subject of investigation

may indicate the mechanical removal of the paper itself, or a washing either with water or with acids, alkalies, or saline solutions. A certain spotted character which follows this latter treatment differs from the changes of color due to age or soiling.

When the heavier strokes—usually the down-strokes—of a writing are thicker and more blurred than usual a removal of sizing, or an original imperfect sizing of the paper, is suggested.

On the other hand, where the strokes are thinner and closer together than usual, the cause is generally the application of resin, which has been added, in all probability, to conceal a previous scratching of the surface.

The spots produced by washing are usually blurred marks bordering the tracings of the character, and in most cases colored.

Restoration of Original Marks.—In order to bring out any traces of ink-marks which have been so far removed as not to be observable by the naked eye, Coulier recommended placing the document between sheets of white filter-paper and passing a hot flat-iron over it, allowing the latter to remain on the spotted parts for a short time.

Warmé preferred to wet the suspected document with alcohol, wrapped in another piece of paper also saturated with alcohol, for the purpose of bringing out as yellow rusty marks all the pen-strokes which had not been entirely removed by the forgers.

This treatment fixes the appearance of the spread lines and colored spots in the space that has been washed and renders more noticeable the stain caused by a partial sizing. In this manner apparently white papers on which at first no traces of characters could be found showed a yellow tinge, denoting the presence of previous writing, and on the application of gallic acid or an infusion of nut-galls characters appeared sufficiently distinct to permit the forgery to be detected.

Chevallier and Lassaigne discovered a very satisfactory method of making previous writings appear by the aid of heat.

The paper to be examined was placed near the fire in a stove, care being taken not to permit it to ignite, but to give it a pale yellow chamois color. In papers which had been deprived by washing of their writing the latter almost immediately reappeared.[1]

CHAPTER XVI.

ALTERATIONS OF THE ORIGINAL IMPORT OF THE DOCUMENT.

Difficulties.—It is difficult to lay down any general rules for guidance in establishing the fact of such alterations where skill has been employed to conceal them. There is usually something forced or unnatural which

[1] Dictionnaire des altérations et falsifications, etc., par E. Baudrimont. Sixième édition, Asselin et Cie, Paris, 1882.

strikes the eye in looking at examples of this kind. They differ from *bona fide* alterations made by an author with no attempt at concealment, but they differ in so many various ways that it is not easy to bring them under one general category.

As a rule, they err on the side of too great care and legibility. A hand which has never made a clear and distinct figure "2," or letter "t," or word "five," here appears for the first time, under suspicious circumstances, to have thrown off ambiguity and to have plainly formed the letter or figure out of one of different character.

It may be that some trick of writing has ordinarily deprived the character of clearness, and in this case the peculiarity appears, but so subordinated that there can be no doubt as to what was intended to be conveyed to the reader.

Such reformations from bad habits in writing are always very suspicious when they occur at critical points and times, and when they show not only a desire to improve a bad handwriting, but to confer a substantial benefit, nowhere else alluded to, upon some one. The aim of the forger has been to make the altered character distinct, in order that no ambiguity shall rob him of the benefit of the change, and this labored effort to be distinct may lead to his detection. In cases where the sense of the sentence is altered by the addition or the elimination of words, the case falls under the general head of complete forgeries, and all the aids to investigation of the characters of handwriting, the constitution of

inks, and the other branches of the subject discussed in this book may be required; but where a part of a letter or integer is grafted on another to change its value, the forgery is as to degree and not kind. In this case the character of the ink in each of the two parts deserves especial attention.

To this class belongs the "raising" of a cheque, or making it transfer a larger sum to the payee by the addition of ciphers, or integers, or the alteration of one digit to another.

Not all the digits are equally easy to change into each other, but a 1 is frequently changed to a 4; or a 3 or 6 to an 8; or a 7 to a 9, etc.

When there are traces of different inks on the same figure, and one kind makes a number inferior to that produced by both together, the probability of a forgery is much heightened.

Writing over a Stroke or Dash, or where One has been removed.—The methods given above for arriving at a conclusion as to which of two crossed lines is above and which below, apply to the first of these cases, but others may be employed. The author has examined a case where the forger, knowing that it was almost impossible to escape detection by erasing a line and afterwards writing over the erasure, determined to write boldly over a filling-out flourish line, (*i.e.*, a line drawn from the end of the last letter in a paragraph diagonally across a blank space, to prevent any words from being added). The intention of this forger was to write the words first, and

subsequently to erase both line and letters, in order to give the impression that they were made contemporaneously. But when the pen approached the diagonally descending flourish line, he showed his hesitation in writing across the flourish line by the alteration of the direction of his line of writing sensibly upward to avoid it, and as this was the only line of writing with this peculiarity, and its direction was parallel to the flourish line before the latter's partial erasure, it left strong evidence of the existence of the flourish line before this line of writing was penned. Where the writing finally did cross a remnant of the flourish line, examination of the crossing in oblique light, by a lens magnifying three or four diameters, showed conclusively that the latter was underneath. He failed in his object, because the ink of the writing was shown to be above the ink of the line, where traces remained, by oblique examination, and a chemical test showed that the two inks were different in constitution. In this case, also, the erasing was purposely done for a considerable space above and below the line, as if to force attention to the fact that the letters of the writing had suffered in the same way as the line itself, and that both were there before the erasing process began.

Writing over an Erasure.—If any one will try the experiment of erasing an ink-mark on ordinary writing-paper, and then writing over the erasure, he will notice a striking difference between the letters on the unaltered and on the altered surface. The latter are broader, and

in most cases, to the unaided eye, darker in color, while the erased spot, if not further treated to some substitute for sizing, may be noticed either when the paper is held between a light and the eye, or when viewed obliquely at a certain angle, or in both cases.

Very frequently it happens that so much of the size and the superficial layer of fibres must be removed that the mark of the ink can be distinctly seen on the reverse side of the paper, and the lines have a distinct border which makes them broader than in the same writing under normal conditions. If a sharp pen be used there is great likelihood that a hole will be made in the paper, or a sputter thrown over the parts adjacent to the erasure.

The latter effect is produced by the entanglement of the point of the pen among the disturbed fibres of the paper and its sudden release when sufficient force is used to carry it along in the direction of the writing.

It is often of importance to know, in case of a blot, whether the erasure it may partially mark were there before the blot, or whether it were made with the object of removing the latter.

Inasmuch as an attempt to correct such a disfigurement would in all probability not be made until the ink had dried, an inspection of the reverse side of the paper will usually furnish satisfactory evidence on the point. If the color of the ink be not more distinct on the under side of the paper than the color of other writing where there was no erasure, it is probable that the erasure was subsequent to the blot.

If the reverse be the case, the opposite conclusion may be drawn. Blots are sometimes used by ignorant persons to conceal the improper manipulation of the paper, but they are not adapted to aid this kind of fraud, and least of all to conceal erasures.

Additions and Interlineations.—The decision as to whether they have been made legitimately and before a paper was executed, or subsequently to its execution, and with fraudulent intent, must be arrived at by a comparison of the handwriting in which the words appear, the ink with which they were written, and the local features of each special case which usually are not wanting.

As an instance of these local accidents which always assist so much in reaching the truth, the following case in the author's experience may be cited. It was claimed by a plaintiff that the paper, of which the important part is represented below, was altered by the insertion of the words "in foll to Dayt," after the cheque had been paid, cancelled by the bank, and returned to the payer. He did not deny that the sum had been paid, but claimed an additional sum still due on the transaction, and charged forgery against the drawer of the cheque.

It happened that part of a letter of one of these words crossed two of the punctures over figures of the cheque, but no ink had come through to the under side, there was no soiling of the edge of the paper by ink, and no way to account for the absence of these appearances, if the cheque had been actually punctured when the words were written. Consequently, the jury very justly gave

a verdict for the defendant, and saved an innocent man from incarceration as a criminal.

In Plate III., Fig. 1, part of the face of the cheque, including the figures for the dollars, and the punctures over them to prevent alteration, is represented.

In Fig. 2 the reverse of the top of the "f" has been lightly traced in pencil to show the direction of its descent over the punctured part on the opposite side, and two arrows have been drawn in pencil to within minute distances of the holes, which the tail of the "f" (written in ink) on the face or opposite side traversed.

Had these holes been there when the "f" was written, the little thread of ink which flowed from the pen upon the paper would inevitably have penetrated them and appeared on the opposite side. As not a trace of ink appears on the reverse side, it is conclusive evidence that the holes were not there when "in foll.to Dayt" was written; or, in short, these words were written before the cheque was cancelled by the bank, and presumably before it was returned to the drawer.

While the expert in handwriting should confine himself to the examinations of the paper, ink, seals, handwriting, etc., and leave to the counsel the task of reasoning on the purport of the words added, and all other matters not allied to those parts of the forgery relating to handwriting, yet it would be unreasonable to neglect altogether any means of corroborating a previously formed suspicion or directing a course of inquiry.

The expert would be more or less than human who

could shut his eyes to the importance of the fact, if certain words of doubtful authenticity gave to the person who might have written them benefits which he would not have procured without them. It is, of course, improper for an expert to allow himself to be influenced in his purely scientific investigation, but he need not deny himself the encouragement which is derived from the discovery of an apparent motive for the act, nor neglect the clue which such a motive might suggest as an additional line of investigation.

Where the supposed writer of the document was a bad or careless penman the interlineations or additions are generally distinguished from his handwriting, which they simulate, by greater clearness and precision, as has been said above; for, if a man will risk being sent to jail for forgery, it is not likely that he is willing to lose, through indistinctness of the characters, any prospective advantage which his felony will bring him.

Obvious Mistakes.—Considering the number of such fraudulent additions or interlineations in the forgeries which come to light, the number of mistakes in spelling or in following the method employed by the supposed writer in forming the same words is surprisingly great. Several instances are recalled where the name of the supposed writer was not only misspelled but spelled in two different ways in the same instrument. It occasionally seems as if the forger's attention is so earnestly directed to overcoming the difficult parts of his task that he neglects the simpler and more obvious parts.

PART IV.

CHEMICAL EXAMINATION.

CHAPTER XVII.

CHEMICAL CONSTITUTION OF INKS.

Schluttig and Neumann's Report.—In the exhaustive essay upon iron-nutgall inks by Schluttig and Neumann in the interest of the ink-manufacturing firm of August Leonhardi, in Dresden (which has been made the basis of most of the important chemical treatises on inks since the date of its publication), the following characteristics are laid down as necessary for a perfect ink:

1. A clear, filterable solution, which shows no particles in suspension.

2. It must be limpid (easily flowing) and remain so for some time,—that is to say, it must flow easily from the pen, and neither stick fast to nor fall from it, nor broaden on touching the paper.

3. It must possess durability in glass (*i.e.*, in the ink-stand), and (*a*) must produce only a slight precipitate after a considerable time, and (*b*) must exhibit no crust on the surface or sides and no flakes.

4. It must produce on the pen only a slight lacquer-like smooth deposit, but not a loose crust.

5. It must possess no pronounced odor.

6. It must not be too acid, nor penetrate good paper.

7. It must have an intense color which neither in the fluid nor on the paper becomes lighter, nor is entirely bleached.

(In the latter case the bleaching is estimated from the time of the attainment of perfect dryness of the writing, because wet lines always appear darker than dry.)

8. It must produce characters which, after drying, are not sticky.

All good inks should possess these characters, whether they are copying-inks or writing-inks. In the foregoing cases only the writing-inks and the combined writing- and copying-inks are considered, which latter, without regard to their copying properties, must have all the qualities of a good ink. The pure copying-inks which make more than two copies are not considered in the following.

Further, it is to be required of the writing-inks that—

9. They must produce characters which, after drying for eight days, cannot be so far removed by several days' treatment with water or alcohol that they will become illegible. With regard to the permanence of their written characters on exposure to light and air they are divided into (*a*) unalterable, or Class I., and (*b*) alterable, or Class II.

The unalterable are the so-called iron-nutgall inks of documentary value: they must possess—

10. A definite minimum content of iron, and

11. A sufficient content of nutgalls,—*i.e.*, they must produce written characters which in eight days turn into deep black, and then even after several days' treatment with water and alcohol still maintain a certain degree of blackness.

After stating that the value of iron-nutgall inks, for use in legal documents, is established beyond peradventure, Schluttig and Neumann add that, although these are the only inks whose permanency has been guaranteed by the results of centuries of exposure, still, not all documents written with so-called iron-nutgall inks can be expected to remain legible for several centuries.

On the other hand, the characters in other documents have been perfectly preserved up to the present day. Although the character of the paper has a certain influence upon the result, yet the conclusion is forced that only such iron-nutgall inks furnish the guarantee of lasting for centuries of which the written characters are really black after drying, and that the same amount of confidence cannot be given to other nutgall iron inks of which the characters are gray or brown.

These chemists regard the introduction of gum or other substance to render the ink viscous as harmful and antiquated.

The above requirements of a good ink are seldom fulfilled, and the student of the writing-fluids employed in documents both old and recent would be very far misled if he were to suppose the objects of his examination to be the dried remains of writing-fluids of such high character.

In the new Danish Ink Standards, published May 16, 1892, in the main all the suggestions made by Schluttig and Neumann in their paper on iron-nutgall inks are adopted. The first two sections in the translation are as follows:

1. Ink for use in government service must fulfil the following general requirements. It must be clear (contain no deposit on the bottom nor solid separated parts); not more acid than is necessary; and must not have too strong an odor. It should have a strong color, and give a like strongly colored writing. When placed in the inkstand it should be able to be kept for some time without the formation of a film on the surface or side walls of the glass, or of a deposit on the bottom, or of mould. On a good pen, after drying, it should leave but an insignificant, glossy coating, but not a loose, scaly crust. It must flow readily from the pen, but must not show any tendency to penetrate good writing-paper too much. The written characters must dry rapidly without becoming sticky, and after drying take a black color.

2. The ink which is employed in the service of the government must belong to one of the following classes.

Class I.—Iron-nutgall ink, which must have the following characteristics. (1) It must contain at least four grams of iron to the liter; (2) it must show perfect permanence for fourteen days. (The test for permanence is made by placing twenty-five cubic centimeters of the filtered ink into a cylindrical medicine bottle of five hundred cubic centimeters' capacity, of which the aperture

has been closed by a paper cover, or in such a way as to exclude dust, etc. In testing for mould its mouth is left open.) (3) It must produce written characters which are as able to withstand light, air, water, and alcohol as those of the ink composed of the following ingredients in one liter: 23.4 grams tannin (from the purest commercial tannic acid,—*i.e.*, so much of the latter as will contain 23.4 grams), 7.7 grams crystallized gallic acid, thirty grams copperas, ten grams gum arabic, 2.5 grams anhydrous HCl (in pure commercial hydrochloric acid), one gram carbolic acid.

The test is made by the exposure of the characters which have been written on a paper of the Class 1 material (rag paper) to direct sunlight for three whole summer months; subsequent washing in the water and alcohol, and drying.

Class II.—Ink of which the characters after eight days' drying can neither be washed out by water nor by alcohol. It is only required of this ink that it withstand for three days the test of permanence prescribed for Class I. But the test for mould should be extended to fourteen days.

Copying-ink must belong to Class I., and furnish good and sharp copies at least during one day after the drying. Even if the writing is not copied, it must not be sticky after drying.[1]

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[1] From the Chemisch-technisches Reportorium, Berlin, 1892. Zweites Halbjahr, Erste Hälfte, p. 46.

Vanadium Inks.—Berzelius found that by treating an infusion of galls with a solution of ammonium vanadate in place of iron sulphate, he could produce an ink of remarkably good quality. At the time of his discovery —1831—it was of no practical interest, because the vanadates were very costly. At the present time their cost has been so much reduced that his formula can be employed for ordinary inks, which have the additional advantage of presenting great resistance to most reagents and destructive materials. Gum arabic can be dispensed with, and the chance of moulding or alteration thus reduced.[1]

The following is a form of specifications prepared by Dr. Bennett F. Davenport, 161 Tremont Street, Boston, Massachusetts:

COMMONWEALTH OF MASSACHUSETTS.

Specifications for a Standard Record Ink to be furnished under Chapter 354 of the Acts of 1899.

It must be a gallo-tannate of iron ink, not inferior in any essential quality to one properly prepared after the following formula, in which all the ingredients are of the quality prescribed by the United States Pharmacopœia, and the per cent. of true acid present in the sample of tannic acid used has been determined by the Loewenthal and Schroeder method.

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[1] "Work shop receipts" (second series), Robert Haldane. London, 1883, p. 329.

Take of pure, dry Tannic Acid, 23.4 parts by weight.
of crystal Gallic Acid, 7.7 parts.
of Ferrous Sulphate, 30.0 parts.
of Gum Arabic, 10.0 parts.
of Diluted Hydrochloric Acid, 25.0 parts.
of Carbolic Acid, 1.0 part.
of Water, sufficient to make up the mixture at the temperature of 60° F. to the volume of 1000 parts by weight of water.

Inks submitted will be subjected to the following tests as compared with the standard ink described above:

1. A fluidounce allowed to stand at rest in a white glass vessel freely exposed, in diffused daylight, for two weeks to the light and air at a temperature of 50° to 60° F., protected against the entrance of dust, must remain as free from deposit upon the surface of the ink or on the bottom or sides of the vessel.

2. It must contain no less iron, and must have a specific gravity of 1.035 to 1.040 at 60° F.

3. It must develop its color as quickly.

5. After a week's exposure to diffused daylight, the color must be as intense a black when used upon the standard record paper, and it must equally resist changes from exposure to light, air, water, or alcohol.

5. It must be as fluid, flow as well, strike no more through the paper, nor remain more sticky immediately after drying.

There would seem to be practical unanimity as to the superiority of iron-nutgall inks for permanent records.

According to Hager and Holdermann,[1] the most frequently employed black inks are prepared from the following substances:

Constitution of the Principal Inks.—1. Gallo-tannic acid (nutgalls), copperas, gum arabic (with or without acetic acid or wood vinegar). Fluid of this character is generally called nutgall ink.

2. Alizarine ink is prepared like that of nutgalls, but receives an addition of indigo-carmine, or a solution in water of indigo in sulphuric acid to which iron has been added.

3. Nutgall ink with logwood is prepared like nutgall ink, but instead of water, a decoction of logwood is employed.

4. Logwood ink (with potassium chromate) is prepared with one thousand parts of a decoction of logwood and one part of potassium chromate.

5. Unknown inks are brought into commerce under different names, but are chiefly prepared from logwood infusions with various salts (such as, for instance, cupric chloride).

6. Copying-inks consist mostly of the foregoing inks, with glycerin and an addition of sugar, or they are prepared from solution of extract of logwood, with the addition of alum, blue vitriol, glycerin, indigo-carmine, etc.

7. Aniline inks are prepared from aniline colors.

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[1] Hager's Untersuchungen, etc., Dr. H. Hager and E. Holdermann. Leipzig: Ernst Günther's Verlag, 1888.

It is often important in the examination of supposed forgeries to know the constitution of the inks more generally employed.

CHAPTER XVIII.

THE TESTING OF INKS.

Objects in View.—The chemical testing of inks on documents may have for its object the decision as to whether two different ink marks give the same reactions; whether certain substances, or what substances, are contained in an ink; which of two crossed lines is the upper, etc. These and a variety of other questions belong to the chemical part of the general subject, and are here to be considered by themselves. It is evident that, in an important document, it is out of the question to think of making a quantitative analysis of an ink. To do so would destroy the document, and even if at this cost a satisfactory analysis could be made (which is more than doubtful), the sacrifice would be too great. It is not likely that a satisfactory quantitative analysis of the ink could be made from the extremely thin and dried films of its marks on paper, for whether mechanical or chemical means were used to collect them, the substance examined would always be rendered impure by the material derived from the surface of the paper, which could not be entirely separated from it.

Furthermore, some constituents of inks are volatile, and consequently the result attained by an ultimate analysis of the material which could be secured from a dried piece of writing would be but little more precise in suggesting the original constitution of the ink than such qualitative tests as may be conducted without injury to the document as a record.

Importance of photographing the Document.—While it is perfectly true, as has been said before in this work, that a good photographic copy should be made of every document before it is submitted to chemical examination, the latter is far from the dangerous process which judges and opposing counsel sometimes seem to consider it.

Chemical Testing.—It is frequently remarkable to observe with what equanimity the court can see an important document soiled by dirty fingers, folded and sometimes torn, pricked with pins, and adorned with "Exhibit" marks, while it forbids the application of a minute drop of a reagent to the ink or paper, of which the effects could be seen only by a magnifying-glass, and which would have some real value in the establishment of the truth: as if the act of testing chemically were a sacrilege. This prejudice of some courts against permitting a document to be chemically tested seems not to be shared to the same extent abroad.

If the truth is to be elicited some liberty must be allowed the agent, but it is not necessary that he should be permitted to mutilate or destroy the paper. On the

contrary, in dealing with valuable documents none should be allowed to apply tests of any kind but those known to have the necessary experience to do so safely, and those who have a respect for records.[1]

The tests applicable to a writing are necessarily qualitative,—that is, they are exclusively directed to determining the presence of a substance and not to the quantity of that substance which exists in the ink. The proof of the presence of a substance is obtained by the reactions it gives, which are in these cases usually changes of color or shade on the application of the testing substance. It is not necessary that this should be effected over any considerable surface of the ink-mark tested. An exceedingly small drop applied on a fine point to a given part of an ink line, and then examined carefully under the magnifying-glass, will give the same assurance of the presence of a component as would the entire document if immersed in the reagent. It is seldom necessary to effect a change so great as to be remarked by a casual glance at the document. Nevertheless, it in no way invalidates the authenticity of a document if the color of parts of a few letters has been changed, especially if the exact parts of the document to which reagents have been applied are noted, and can be

[1] In a case known to the author a handwriting expert who was no chemist, to whom a promissory note in dispute had been submitted, so defaced it that all the characters were smeared and with difficulty decipherable, while the figures indicating the sum were absolutely obliterated.

recognized and testified to by the expert who makes the experiment. The lines should remain in other respects as distinct as before. This would generally be the case, but there are tests which leave the ink spread out in little blots where the reagent has been applied. Tests like these should be avoided wherever possible, and when necessary the amount of the reagent should be as small as is consistent with a proper observation of the reaction.

For the purpose of examining inks upon written documents, the following are the reagents which it will usually be found sufficient to employ:

Reagents Desirable.—Oxalic acid, ten per cent. solution; citric or tartaric acid, ten per cent. solution; hydrochloric acid, ten per cent.; sulphuric acid, fifteen per cent.; nitric acid, twenty per cent.; a solution of one part tin dichloride, one part hydrochloric acid, and ten parts of distilled water; saturated solution of sulphurous acid; four per cent. solution of gold chloride; a solution of sodium hyposulphite one part, ammonia one part, and distilled water ten parts; a solution (which should always be freshly made) of potassium ferrocyanide one part, hydrochloric acid one part, and distilled water ten parts; a solution of potassium sulphocyanate one part, hydrochloric acid one part, and distilled water ten parts; a four per cent. solution of sodium hydrate in distilled water; a two per cent. solution of chlorinated lime; some crystals of iodine; absolute alcohol; aqua ammonia; and distilled water.

Convenient Form of Apparatus.—The author finds it convenient to arrange these reagents in a portable case of which a representation is given in Plate XIII., Figs. 5 and 6.

The little reagent bottles, each containing about twenty cubic centimeters, are held in separate compartments, on two sides of a double strip, hinged at the top. In carrying, the two strips are pressed together and slipped into the grooves on the ends of the outside case; while in use, the strips are separated and rested on the table, when they are ready at hand. A broad pocket extending over the entire length of the outside case is useful for carrying the glass rods, feathers, pens, etc., necessary for applying the reagents.

Manner of Testing.—Strips of clean, white blotting-paper should always be provided before commencing the examination.

If the document be very old or the ink with which it is written very pale, it is well to apply a drop of distilled water to the place where the reagent has been applied, and as soon as sufficient time has been allowed for judging of the reaction, to remove the surplus fluid at once by means of the blotting-paper.

The testing of a writing demands every precaution, for often only one written letter, a simple stroke, constitutes the object of the examination, and it must be proved from this stroke whether it has been made with other ink than that used in the rest of the document. Again, sometimes the proof must be furnished whether a writ-

ten character is of later date than the remainder of the document.

When important documents are concerned, and especially in legal cases, as has been reiterated, it is advisable to have a photographic copy taken of the writing, or the suspected part of the writing.

Preliminary Investigation.—At the commencement of the investigation one should use a lens or a magnifying-glass in order to determine whether several adjacent characters have apparently been made with the same ink. They should be viewed with a magnifying-glass in reflected and transmitted light in order to recognize a variation in color, lustre, or thickness of the ink-film. Many inks blot on bad paper,—that is, the written characters surround themselves with a paler border; other inks, for example, such as those which contain much gum, do not possess this characteristic.

The lens determines this easily, but it must not be overlooked that many papers are badly sized, or have individual spots which are not sufficiently sized, and hence cause the ink to flow. An ink rich in gum, or an ink concentrated by evaporation in an inkstand, gives a more lustrous and thicker stroke. Many inks sink deeper into the material written on, so that the character can be seen and observed on the other side of the paper with the lens. At the place where written characters cross, and these written characters have been made at different times, or with different inks, it can often be recognized, with the aid of a lens, which character lies under or

over the other, and therefore which was made first or last. (See Chapter VI.) If it be necessary to employ the microscope, a magnifying power of tenfold linear measure with a lateral illuminating lens is generally strong enough.

REAGENTS AND REACTIONS.

Oxalic Acid ($H_2C_2O_4 + 2Aq$).—With a soft quill or gold pen which has been dipped in solution of oxalic acid (one part acid to ten or fifteen parts of distilled water), minute dots are made on, or cross-strokes are made through the broader and narrower parts of some of the written characters, and these are examined by the naked eye after drying, and with the lens. With iron-holding inks a fading or paling will occur more quickly in fresh writings, and more slowly in old writings. Fresh characters traced in nutgall ink one or two days before the observation disappear under oxalic acid easily, or become light gray; older characters become a little paler or gray, and the same is true of nutgall ink with logwood; the characters written with alizarine ink become by solution of oxalic acid bluish or blue; characters made with logwood inks, on the other hand, orange-red, raspberry-red, or brownish-red. Aniline ink is not materially changed.

Hydrochloric Acid (HCl).—The pen is dipped in ten per cent. hydrochloric acid, and strokes are made

as before through separate parts of the writing, and allowed to dry without warming. Writings of nutgall ink, if not more than a day old, become yellow; if older, yellowish-gray; those with nutgall ink containing logwood, reddish or reddish-gray; with alizarine ink, greenish; logwood inks, more or less red; aniline ink, more or less reddish or brownish-gray.

It is well to bear in mind that the best commercial inks are composed of iron tanno-gallate with a permanent blue to make the fresh writing sufficiently distinct, as the black color of the iron-nutgall inks is produced only after a few days or weeks. In case this blue coloring-matter be unaltered by dilute hydrochloric acid, the effect of this reagent on such an ink will be to produce a green by the mechanical mixture of the yellow iron sesquichloride with the added blue substance. This result may lead to an erroneous belief that aniline black or alkali blue is present.[1]

Ammonium Hydrate (NH_4OH).—This substance, known in commerce simply as ammonia or hartshorn, is one of the three strongest alkalies. It is preferable as a reagent to potassium or sodium hydrates, because it is entirely volatile, and any excess which may be left on

[1] This observation was made by the Chemist of the Health Department of New York City, who called the author's attention to it at the time the latter was making the chemical tests of inks in the exhibits of "The People *vs.* Roland B. Molineux," for the District Attorney.

the substance to which it is applied may be entirely expelled by moderate heat. Ammonium hydrate is very subject to the capillary action of the paper, and runs over a large space outside of that to which it is applied. The use of parallel strips of blotting-paper is to be recommended when it is applied to a written instrument.

In moist ammoniacal air, or in contact with caustic ammonia, the places in the writing which have been changed in color by acids become darker (even blackish violet, like the logwood inks), frequently with blurred outlines; but the writings least of all, or not at all darkened are those made with nutgall ink and bleached by acids.

Potassium Ferrocyanide ($K_4Fe(CN)_6$).—Ferrocyanogen forms with most metals compounds insoluble in water, and usually exhibiting characteristic colors. Its compound with iron, even when an infinitesimal amount of the latter is present as a sesquioxide or sesquisalt, produces an intense blue—Prussian blue—which is not affected by hydrochloric acid, but is dissolved by potassium hydrate.

In using this reagent on a document for the purpose of proving the presence of iron in the ink unusual precautions are necessary. In the first place, as has been stated in the remarks on the constitution of paper, small drops of the reagent should be applied to the paper of the document, and left each for a minute at parts where there is no ink. If no change of color take place,

the drop should be removed by soft blotting-paper, and its traces still further obliterated by successive drops of distilled water on the same spot, also removed by blotting-paper.

The reagent should then be applied in a minute drop to the ink. If, at the expiration of sixty seconds, no change of color appear in the drop or on the paper under it, the solution should be removed by bibulous paper, and the place washed by successive drops of distilled water, which should be allowed to stand for an equal time, and removed in the same way. If the solution be exposed to the light and air it will suffer decomposition, and part of its iron contents will furnish the very reaction for iron which is sought in the material to which it is applied.

Documents which have been tested by the reagent without having been subsequently sufficiently washed, as above suggested, invariably exhibit blue spots which ignorant or designing persons may ascribe to reactions with the iron in the ink or paper when no iron was present in either.

While this reagent is valuable, it requires more care than any other to avoid leaving a stain on the document. It should not be applied in drops broader than the ink lines it is meant to test, but rather in very minute drops lying wholly within the lines; and the reaction, if any, should be observed with a glass magnifying four or five diameters. If no reaction for iron be observed on the blank paper, while a reaction is seen when the reagent

touches the ink, the proof is convincing that the color is due to the iron in the ink.[1]

Potassium Sulphocyanate (KSCN).—This reagent, when acidulated, as recommended in the table of reagents, or, indeed, in all but distinctly alkaline solutions of iron sesquioxide salts, produces in them an intense red color, although not a precipitate.

This test is one of the most delicate in qualitative chemistry, and, in the absence of molybdenum dioxide and hyponitric acid (which, in most cases, may be safely assumed), is convincing as to the presence of iron in the ink. Indeed, its very delicacy, which takes note of the adventitious existence of the minutest particles

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[1] This test proved of great value in the Whitaker will trial. A will, purporting to have been made by Robert Whitaker, on the 7th of May, 1875 (a copy of the last page of which will be found among the illustrations of this book), was presented for probate upon his death in 1878. The appearance of the ink with which the signatures were written was of that peculiar reddish-brown assumed by iron inks after the lapse of several years. If it were an iron ink, therefore, it must give, with potassium ferrocyanide, the blue color characteristic of this element. If, on the contrary, it gave no reaction for iron, it was no common writing-fluid, but a coloring-matter chosen to imitate an oxidized iron ink. So thought the author, who was requested to examine the will. The writing-fluid proved to be an unusual one containing no iron but simulating old iron ink, and he reported it to be probably Winsor and Newton's brown, which was subsequently corroborated by the confession of the forgers.

of ferriferous substances in paper or ink, is almost a drawback to its use for arriving at a conclusion when it gives the reaction for iron; but when even this substance fails to show the slightest trace of iron it is useless to seek proof of such a trace by any other test. It has also the advantage over potassium ferrocyanide of not containing iron within itself, which by internal decomposition may produce the very substance it is employed to detect.

Tartaric Acid ($H_2C_4H_4O_6$).—That of commerce is sufficiently pure for purposes of testing. It is to be kept as a powder, and a solution made when required, for it decomposes by exposure to light and air, as can be observed when a white film forms on its upper surface.

Citric Acid ($H_3C_6H_5O_7 + 1Aq$), like tartaric acid, is useful in preventing iron sesquioxide solutions from precipitation by alkalies; it dissolves iron sesquioxide, and therefore bleaches an ink of which the dried film contains this substance.

Sulphuric Acid (H_2SO_4).—The reactions of this powerful acid are well known. It readily dissolves the sesquisalts of iron in an ink-film and produces characteristic color reactions with the various inks.

Nitric Acid (HNO_3) is, like the preceding, well known to chemists and non-chemists. It is a powerful oxidizing

agent and solvent, and its salts are generally easily soluble in water.

Acidified Tin Dichloride ($SnCl_2.HCl$).—This is a powerful deoxidizing or reducing agent.

It extracts the oxygen present in the ink-film, and breaks up the compounds, while the free hydrochloric acid removes the iron.

This reagent is difficult to preserve for use, and should be made when needed. It should be kept in a well-stoppered bottle slightly acidulated with hydrochloric acid, and some metallic tin should be added. Its tendency is to form tin perchloride, which destroys its value as a reagent.

Gold Terchloride ($AuCl_3$).—This solution is used as a strong oxidizing agent. In the act of oxidizing it precipitates metallic gold as a reddish-brown powder.

It is not so subject to change in the reagent-bottle as the substances just considered.

Ammoniacal Sodium Hyposulphite ($Na_2S_2O_3 + NH_4OH + Aq$).—This well-known reagent, employed extensively in photography, has powerful reducing properties, and reacts on the various constituents of inks with characteristic color effects noted in the table at the end of Part IV.

Sodium Hydrate ($NaOH$).—This is one of the two strongest alkalies, and is employed both for neutralizing

acids previously applied to portions of the paper, and for its decomposition and color-indications on the materials to which it is applied. (See table.)

Chlorinated Lime ($CaOCl_2$).—This is simply the bleaching powder of commerce dissolved in water. It has a bleaching and an oxidizing effect, the two being due to the same characteristic, the release of oxygen by the free chlorine and the destruction of coloring-matter by the former. Like all the other reagents, but with greater reason than for any except perhaps strong sulphuric and nitric acids, it should not be left in contact with the document longer than is necessary for the observation of the reaction, otherwise it is liable to injure or destroy the latter.

Iodine (I_2—crystals).—This element is volatile, even at ordinary temperature, and is characterized by its strong blue color when brought in contact with starch. Its uses are more particularly set forth further on. This reaction was supposed to be merely physical, but the best authorities now regard it as a true chemical combination, and Mylius finds the starch compound to contain eighteen per cent. of iodine, of which part is hydrogen iodide,[1] and gives the formula $(C_{24}H_{40}O_{20}I_4)HI$.

Alcohol ($C_2H_5(OH)$).—The use of this substance as a test on portions of a paper where writing has been

[1] Sadtler.

erased, and the bare place has been resized by means of resin, soap, and paste, or other like substances, has been already alluded to. Besides this, however, it is of value in causing the reappearance of writing which has been rendered invisible, as described in the experiments of Chevallier and Lassaigne in a succeeding page. Care is necessary in using alcohol on documents on account of its strong tendency to spread and run over a large area of the sheet, carrying its stain and coloring materials to a considerable distance from the spot to be tested. Where this would interfere with the investigation, it is recommended to place strips of blotting-paper on either side of and close to the spot to be treated with alcohol, and to press them firmly upon the document before applying the small drop of alcohol between them.

TWO EXAMPLES FOR CHEMICAL INVESTIGATION.

Superposition in Crossed Lines.—To distinguish, chemically, the ages of two ink-films which cross each other; whether, for instance, a crossing out, a writing, or a blot were first made (if iron-nutgall was the ink used), the place is touched with a brush dipped in the solution of oxalic acid described above, because it can be assumed that the upper ink-film will bleach sooner than the under and older, which has penetrated deeper into the paper fibres. If a logwood ink have been used for crossing out, it can be made to disappear by touching with ammonia. If the overlying ink is nutgall ink, and the writing log-

wood, the proper place should be repeatedly moistened with oxalic acid or solution of potassium fluoride acidified by sulphuric acid until it has become so pale that the lower writing can be read.

During this operation the moistened part should frequently be observed in a good light. If the ink-film to be removed is very thin, and if the writing covered by it consist of fine strokes, it is recommended to saturate blotting-paper with the acid or the ammonia and by tapping and pressing upon it to take up the ink-film. When the covering ink-film is removed, if the writing be more or less attacked, it is allowed to dry without warming. In the case of nutgall inks, it is touched with a small quantity of a solution of gallic acid; and in the case of logwood ink, with a very dilute solution of chloride of copper; and is again allowed to dry without warming.

Approximate Age of Writing.—To assist in determining the ages of writings by one and the same ink, it is to be observed that the older the writing the less soluble it is in dilute ammonia. If the writing be lightly touched with a brush dipped in ten per cent. ammonia, the later writing should, theoretically, always give up more or less soluble matter to the ammonia before the earlier. In case of inks of different kinds this test is not serviceable, for characters written in logwood ink, for instance, will give up their soluble material sooner than nutgall inks, even if the last named be later applied. An estimate of the age of a writing from the amount of bleaching in a given time by hydrochloric or oxalic acid

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is very unreliable, because the thickness of the ink-film in a written character is not always the same, and the acid bleaches the thinner layer sooner than the thicker.

(See later to determine the age of a writing according to Carré).

It should be borne in mind that rules as to comparative solubility, etc., of similar substances which have been exposed to a constant decomposition for different lengths of time, are applicable inversely to the amount of the difference in length between the period which elapsed between the latest of the writings and the date of observation, and that between the dates of the writings themselves. For example, if a year elapsed between the date of the latest writing and the observation, and a month between the two writings, it should be easy to detect which was the older. But after a lapse of ten years it is very doubtful if a difference of age could be shown, unless the two writings crossed each other, when the order in which the intersecting marks were placed upon the paper can usually be ascertained at any subsequent date. But it is seldom, if ever, possible to fix the *length* of the period which elapsed between two writings.

HAGER'S METHOD.[1]

Reagents used by Forgers.—The forging of papers by the removal of written characters may be accom-

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[1] Hager's Untersuchungen, Zweiter Band: Leipzig, Ernst Günthers Verlag, 1888.

plished in one of two ways,—either by erasure or by washing with chemical reagents.

The erased place is usually covered by rubbing with sandarach powder, an alum powder, or a partial sizing.

To the chemical washing reagents belong oxalic acid, citric acid, hydrochloric acid, potassium oxalate, chlorine, chlorinated lime solution, and acid sodium sulphite. For the purpose of establishing a forgery of writing of this kind, observe the surface of the paper, whether it is rough or smooth, whether the particular place exhibit any difference in reflected and in transmitted light, as well as by feeling with the fingers. The place in question is either rough or smooth, or rubbed with the previously mentioned powders, or it possesses a greater transparency and is thinner.

In hand-made paper (which at present is but rarely met with, and is but superficially sized) the erased places are easier to detect than in machine-made paper.

The sizing which is applied to ordinary writing-paper is a paste holding resin soap. In order to heighten the white of the paper, a blue material, either ultramarine or Berlin blue, is added. On the other hand, almost every paper contains traces of iron derived from the water which is used in its manufacture.

If the forgery of the writing have been effected by the aid of chemical means, certain changes in the color of the paper will be noticeable. On the places in question

will be found gray, yellow, or white spots, recognizable in reflected and transmitted light.

Reagents in the Cold.—A piece of slightly moist litmus paper is laid on the suspected place and pressed strongly. If acid still stick to the document's surface (oxalic, citric), the litmus paper will be reddened. After this test the suspected area is exposed to the action of ammonia gas, by laying it on a beaker glass in which is some spirit of sal ammoniac. In an hour the parts of the paper where the ink-decomposing reagents acted will have shown themselves changed, or the written characters which have been disturbed will appear in some different shade or color. If the change have taken place in consequence of the action of ammonia gas, but only with moderate distinctness, the place is touched over gently with a mixture of equal parts of dilute ammonia and ninety per cent. alcohol. If nothing appear by this method, the moistened place is allowed to become dry and then is painted over with a solution of one part gallic acid or gallo-tannic acid in twenty parts of forty-five per cent. alcohol. If particles of iron oxide from the decomposed written characters are found in the mass of the paper fibre, they will now appear perhaps somewhat blurred. If the paper contain in itself oxide of iron (recognizable by the yellow or brownish-yellow color), it is advisable, instead of gallic acid or gallo-tannic acid, to employ a dilute solution of potassium ferrocyanide in water. This latter is to be recommended if the above acids have given no result.

If the ink with which the decomposed letters were made contained copper salts, or iron and copper salts, this should insure a reaction.

Heating in Presence of Reagents.—Heating the paper with chemical reagents is recommended (by Chevallier and Lassaigne) in the investigation of forgeries. The paper, previously moistened with alcohol, should be heated directly at the fire, or laid between two paper sheets and pressed by a hot iron until the upper sheet browns feebly, or becomes the color of chamois skin. This operation must be conducted with the greatest caution.

Another experiment recommended consists in the action of iodine vapor on the paper. A few iodine crystals are placed in a flat glass vessel which is covered by the suspected parts of the paper. In fifteen to thirty minutes the paper will have been colored yellowish, and the erased portions, or the places which contained writing, will appear surrounded by a colored border.

It is, nevertheless, advisable that a previous experiment be made with the same paper in order to ascertain its behavior to iodine. If it be colored very deeply by iodine vapor, the color can be again removed by vapor of ammonia.

Whether the one or the other reagent be employed, a preliminary experiment with the same paper is always to be undertaken in order to observe its behavior to the reagent.

Cases can very well occur where a reagent cannot be employed, if the paper thereby will be darkly colored.[1]

Determination of Age.—The determination of the age of a written paper is a problem difficult of solution. According to F. Carré the age can be approximately determined if the characters written in iron ink are pressed in a copying-press, a commercial hydrochloric acid diluted with eleven parts of water being substituted for the water as ordinarily used; or, if the written characters be treated for some time with this diluted acid.

The explanation is that the ink changes in time; its organic substance disappears little by little, and leaves behind an iron compound, which in part is not attacked even by acids.

An unsized paper is impregnated with the described dilute acid, and a copy taken by means of a press. A copy from a writing eight or ten years old can be obtained as easily as one by means of water from a writing one day old.

A writing thirty years old gives, by this method, a copy hardly legible, and one over sixty years old, a copy hardly visible.

In order to protect the paper against the action of the acid, it should be drawn through ammoniacal water after the experiment.

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[1] For documents the paper should be manufactured from a pulp which has received an addition of potassium ferrocyanide, caustic ammonia, and protochloride of iron.

Sympathetic Inks.—The discovery and proof of the use of sympathetic ink are sometimes required of the expert. Solutions of salts of cobalt, nickel, lead, copper, ferrous oxide, mercurous oxide, potassium ferrocyanide, besides solution of potassium iodide, diluted sulphuric acid, onion-juice, tannic acid, gallic acid, and radish-juice, furnish material for sympathetic inks.

First, heat must be applied, the paper being held over a lamp with a glass cylinder until a slight browning occurs.

Characters made with cobalt salt appear blue, those with nickel salt green, those with the sulphuric acid and plant-juice gray or blackish.

If the warming produce no result, cross-lines are made across the paper sheet by means of a very soft goose-quill dipped in a reagent.

The appropriate reagents are: 1, gallo-tannic acid; 2, potassium ferrocyanide acidified with a little sulphuric acid; 3, hydrogen-sulphide water; 4, ammonium sulphide; 5, copper vitriol; 6, iron vitriol; 7, solution of potassium iodide; 8, caustic ammonia; 9, lime-water.

Procedure.—Blotting-paper is saturated with the particular reagent which is to produce a color reaction, and pressed strongly on the paper containing the invisible writing; or the latter is drawn quickly through a dilute solution of the reagent. If neither heating nor reagent produce a result, vapor of iodine is allowed to act upon it, by laying the paper in a saucer or plate, of which the bottom is covered with iodine crystals; and if in this way no result be obtained, the paper is strewn

with burnt ivory or fine charcoal powder, and a sheet of paper is laid over it and pressed. When the charcoal powder is removed by light tapping, enough dust remains in contact with the written characters, which have been made with some indifferent substance (dextrin, gum, glue, etc.), to render the writing legible.

Writings with sympathetic inks are not always to be sought on sheets of apparently plain white paper; more frequently they are found on the margins or between the lines of epistles written with black ink, on the margins of printed documents, or the parts of notes uncovered by writing.

If the piece of writing be observed in oblique illumination, some of the written characters usually fainter than the ordinary text can be seen, if not deciphered.

The paper may also be laid between glass plates and observed by transmitted sunlight.

BAUDRIMONT METHOD.[1]

Reagents needed.—The reagents needed in this investigation are alcohol, reagent papers, silver nitrate, and some others.

Distilled water is very useful in many cases to ascertain whether the paper has been scratched and partially sized or treated with resin. If it has not been altered

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[1] Dictionnaire des altérations et falsifications des substances alimentaires, etc., par E. Baudrimont. Paris: Asselin et Cie, 1882.

by chemical agents, this partial resizing and the resinous matter employed give it a peculiar appearance. Sizing takes away from its whiteness and, thinned by the scratching or washing, it absorbs water much more quickly, even when it has been partially resized.

Mode of Operation.—Place the document suspected of being a forgery on a sheet of white paper or, better still, on a piece of glass; then moisten all parts of it, little by little, by means of a paint-brush, paying close attention to the behavior of the liquid as it comes in contact with the paper.

Water.—By means of water one can discover what acids, alkalis, or salts the parts of the paper with colored borders or white spots contain.

With the aid of a pipette cover these spots with water and let it remain for ten or fifteen minutes; then with the pipette remove the liquid and examine the products it holds in solution. Afterwards make a comparative experiment on another part of the paper which is neither spotted nor whitened.

If the original writing have been done with a very acid ink on a paper containing a carbonate, such as calcium carbonate, the ink, in attacking the calcareous salt, stains the paper, so that if the forger have removed the ferruginous salts this removal is denoted by the semi-transparence that water gives to the paper.

To study carefully the action of the water it is necessary to repeat the experiment several times, allowing the paper to dry thoroughly before recommencing it.

Alcohol.—According to Tarry, it is necessary to have recourse to alcohol to discover whether the paper has been scratched in any of the parts and then covered with a resinous matter to prevent the ink from blotting.

Place the document on a sheet of white paper and with a paint-brush dipped in alcohol of specific gravity about 0.86 cover the place supposed to have been tampered with. It may be discovered if the writing thickens and runs when the alcohol has dissolved the resin.

Hold the paper moistened with alcohol between the eye and the light: the thinning of the paper shows the work of the forger.

Some more skilful forgers use paste and resin at the same time to mask their fraudulent operations; in this case lukewarm water should be first employed and then alcohol; water to dilute the paste, and alcohol to dissolve the resin. The result is that the added ink spreads on the places scratched, and the forgery is easily seen.

Test-papers.—Test-papers (litmus, mauve, and Georgina paper) serve to determine whether a paper has been washed either with chemical agents, and the acids incompletely removed or their surplus saturated by an alkali, or by alkaline substances. The change of the color to red indicates an acid substance; an alkali would turn the reddened litmus paper to blue, and the mauve and Georgina test-papers to green.

Take a sheet of test-paper of the same dimensions as the document to be examined, moisten it, and cover it underneath with a sheet of Swedish filter-paper. These

two sheets together (the filter-paper underneath) are then applied to the document which has been moistened already. The whole is then laid between two quires of paper, covered by a weighted board, and left in contact for about an hour.

At the end of this time examine the test-paper to see if it has partly or entirely changed color. This examination finished, add to the test-paper distilled water, which may be afterwards removed and appropriately tested. to discover the nature of the alkali or acid present. Instead of test-papers, tinctures of litmus, mauve, or purple dahlia may be used.

Silver Nitrate.—Silver nitrate is used to discover whether the paper has been washed with chlorine or chlorides. A paper in that way becomes acid. The chlorine changes to hydrochloric acid, which dissolves in the water with which the suspected document is moistened, and at the contact of silver nitrate little spots of silver chloride appear.

Various other Tests.—Certain reagents, such as gallo-tannic acid or infusion of nutgalls prepared a short time before, potassium ferrocyanide, alkaline sulphites, and hydrogen sulphide, may all be used with advantage to restore writings that have been removed by washing. Place the document on a sheet of white paper and moisten the whole of its surface with a paint-brush dipped in the reagent, taking care not to rub it or strongly press it. When the surface is well impregnated allow the solution to act for an hour, and at the end of

this time examine the document again. Then moisten it a second time, and the following day examine the results. Repeat the moistening several times if necessary, for it often takes some time to make the traces of writing reappear.

Use of the Vapor of Iodine.—Chevallier and Lassaigne experimented together on the effect produced by the vapor of iodine on the surface of papers or documents upon which the alteration of writing was suspected. Take a bottle with a wide mouth from ten to eleven centimeters in height, and the opening from five to six centimeters in width. This last is covered by a disk of unpolished glass. Into the bottom of this vessel introduce from twenty to thirty grams of iodine in crystals.

Place the portion of paper on which the vapor of iodine is to act at the opening of the bottle, and cover it with the disk of unpolished glass, on which put a weight so as to exert a slight pressure, and in order that the aperture may be hermetically closed. Then allow the vapor of iodine to act on the dry paper for three or four minutes at the temperature of 15° to 16° (Cent.) and examine it attentively. When the surface has not been spotted by any liquid (water, alcohol, salt water, vinegar, saliva, tears, urine, acids, acid-salts, or alkalis) a uniform pale-yellow or yellowish-brown tinge will be noticed on all parts of the paper exposed to the vapor of iodine. Otherwise a different and easily distinguished tinge shows itself on the surface that has been moistened and then dried in the open air.

Machine-made papers with starchy and resinous sizing give such decided reactions that sometimes it is possible to distinguish by the color the portion of the paper treated with alcohol from that moistened with water. The spot produced by alcohol takes a bistre-yellow tinge; that formed by water becomes a violet-blue, more or less deep, after having dried at an ordinary temperature. As to the spots produced by other aqueous liquids, they approach in appearance (though not in intensity) those occasioned by pure water. Feeble acids, or those diluted by water, act like water; but the concentrated mineral acids, in altering more or less the substances of the sizing, produce spots that present differences.

The spots which become apparent in using the vapor of iodine are due to chemical agents whose strength has altered either the fibres of the surface, or the paste uniting them. For this reason stamped papers, whose preparation and sale are superintended by the French, or other, governments, are less easy to falsify than ordinary machine-made papers.

In a word, the test of a paper by vapor of iodine has the double advantage of indicating the place of the supposed alteration and operating afterwards with appropriate reagents to bring back the traces of ink. The appearance of former letters or figures written or effaced demonstrates forgery.

The difference of the action of the vapor of iodine on the surface of a paper which is not homogeneous permits one to judge whether or not it has received, in certain

parts limited in area, a fine layer of some glutinous matter (gum, gelatin, or flour paste) to make it adhere to other sheets of paper.

This method of testing may be tried at the same time with that which consists in proving this addition, either by the reflection of incident light on paper inclined at a certain angle or by the transmission of daylight or artificial light through the same paper.

Machine-made papers and stamped papers take a violet-blue color in the parts covered by starchy paste, but with the first a more intense color is produced in the parts treated with a thin layer of gum arabic, fish-glue, or gelatin, whereas these same substances spread on certain parts of the surface of stamped papers become neither darker nor yellower than the parts free from it: nevertheless on looking at the light incident to the surface of the paper held obliquely, it is easy to distinguish the parts to which these various substances have been applied.

Table V. is a useful compendium of the more usual tests which may be applied to the inks of written documents. It was published originally in the *Pharmaceutische Central-Halle*, *Neue Folge*, 1892, No. 13, p. 225, by A. Robertson and J. Hofmann, and has been amplified by the insertion of various notes made by the author of this book since that time.

TABLE V.—TESTS FOR INKS.

Draw a moistened quill or gold pen over the ink-mark, and observe with a magnifying-glass.

REAGENTS.	INKS. Iron Gallo-Tannate. "Nutgall."	(a) Logwood with K_2CrO_4.	Logwood with $CuSO_4$.	(b) Nigrosin.	(c) Vanadium.	(d) Resorcinol.	(e) Aniline Black.	(f) Alkali Blue.
Oxalic Acid, 10 per cent.	Disappears.	Violet.	Orange-yellow.	Unaltered.	Bleached and runs slightly.	Bright red.		
Citric or Tartaric Acid, 10 per cent.	Bleached.	Violet.	Orange-yellow.	Runs and becomes dark blue.	Bleached and runs.	Disappears.		
HCl, 10 per cent.	Disappears, leaving a yellow color.	Purple-red.	Blood-red.	Little altered.	Bleached slightly, runs slightly.	Bright rose	Greenish.[1]	Green.
H_2SO_4, 15 per cent.	Disappears.	Red.	Purple-red.	Unaltered.	Bleached slightly.	Bright red.		
HNO_3, 20 per cent.	Disappears.	Red.	Purple-red.	Runs slightly.	Bleached slightly.	Bright rose.		
$SnCl_2$, 1 pt. HCl, 1 pt. Water, 10 pts.	Disappears.	Red.	Magenta-red.	Unaltered.	Bleached slightly.	Disappears.		
SO_2 (sat. sol.)[3]	Bleached.	Gray-violet.	Red.	Unaltered.	Bleached slightly and runs.	Bleached.		
$AuCl_3$, 1 per cent.	Bleached slightly.	Red-brown.	Brown.	Unaltered.	Unaltered.	Becomes brown and runs.		
$Na_2S_2O_3$, 1 pt. Aq. Ammonia, 1 pt. Water, 10 pts.	Dark red.	Unaltered.	Dark blue.	Becomes dark violet and runs.	Runs freely.	Brown.		
$K_4Fe(CN)_6$, 1 pt. HCl, 1 pt. Water, 10 pts.	Blue.	Red.	Brick-red.	Unaltered.	Unaltered.	Rose.		
NaHO, 1 per cent.	Dark red.	Brown.	Becomes dark red and runs.	Becomes dark violet and runs.	Becomes dirty brown and runs.	Unaltered.	Red.	Red.
Chlorinated Lime, 2 per cent.	Disappears.	Disappears.	Disappears, leaving a yellow color.	Brown.	Unaltered.	Brown.		
KSCN. Alcohol. Ammonia. Distilled Water.	The special uses of these reagents will be found in the preceding pages.							

[1] Yellow ferric chloride in presence of a permanent blue, such as is often mixed with iron-nutgall inks, gives also a green color.
[2] Iron-nutgall inks produce also a red with this reagent.
[3] At a temperature of 16° C. and 760 mm. barom. 1 vol. water is saturated by 42.2 vols. SO_2, and 1 part by weight water by 0.161 pts. SO_2.

(*a*) The formula of hæmatoxylin, the coloring matter of logwood, is $C_{16}H_{14}O_6 + 3Aq$.

(*b*) Coupier's gray, or Nigrosin, is prepared by heating nitrophenol with aniline and aniline hydrochlorate. The alcohol-soluble compound is the simple salt of the base, while the sodium sulphonate forms the water-soluble compound.

Coupier's blue is Induline, made by heating amido-azo-benzene with aniline to 160° C. (Sadtler, Industr. Org. Chem.)

(*c*) "Magenta," or "Aniline Red," is the chlorhydrate of Rosaniline. The introduction of the phenyl group, C_6H_5, into this molecule changes the red through violet shades into blue. Hence, triphenyl-rosaniline chlorhydrate is "Aniline Blue." This color, which is spirit-soluble, is made water-soluble by sulphonating, and is thus known as "alkali blue" or "water blue."

The Rosaniline molecule is :

$$(OH)C\left\{\begin{array}{l} C_6H_3(CH_3)NH_2. \\ C_6H_4. \quad NH_2. \\ C_6H_4. \quad NH_2. \end{array}\right.$$

(*d*) See Vanadium inks, p. 191.

(*e*) The Resorcin molecule is $C_6H_4(OH)_2$.

(*f*) For aniline black, aniline chlorhydrate is carefully oxidized : $KClO_3$, and $CuSO_4$ and NH_4 Vanadate are used.

APPENDIX.

A.

FORMULAS FOR DETERMINING THE ABSOLUTE ABSORPTIVE POWER OF A GIVEN INK-MARK FOR SPECIFIED COLORED RAYS, IN UNITS OF A STANDARD WHITE LIGHT, BY MEASUREMENTS OF THE RESPECTIVE THICKNESSES OF COLORED-GLASS PRISMS AT WHICH A MAXIMUM DARKENING OCCURS WITH A GIVEN ANGLE OF THE INCIDENT RAY.

BY GEORGE H. HALLETT, PH.D., UNIVERSITY OF PENNSYLVANIA.

Let it be required to measure the absorptive power of an ink-line for the red, the yellow, and the blue rays by means of red, of yellow, and of blue glass, respectively.

Let R $=$ the coefficient of absorption of the yellow and blue rays of standard white light by the standard red glass prism (*i.e.*, the fraction of total yellow and blue rays which a thickness of one millimeter of the red prism will absorb).

Let Y $=$ the coefficient of absorption of the red and blue rays of standard white light by the standard yellow prism.

Let B $=$ the coefficient of absorption of the red and yellow rays of standard white light by the standard blüe prism.

Let $R' =$ the fraction of the yellow and blue rays absorbed by the ink-line under the red prism.

Let $Y' =$ the fraction of the red and blue rays absorbed by the ink-line under the yellow prism.

Let $B' =$ the fraction of the red and yellow rays absorbed by the ink-line under the blue prism.

Let θ $=$ Angle of prism BOA.

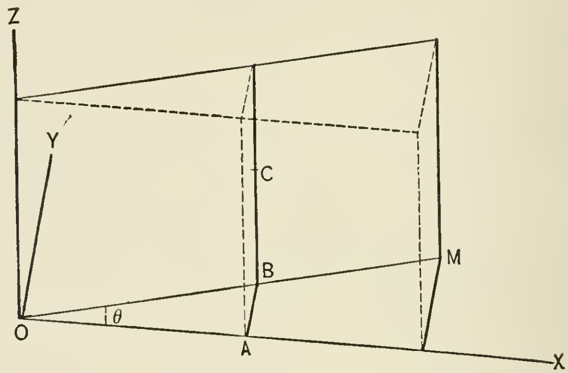
Then: The fraction of the yellow and blue rays absorbed by the red prism at point $(a,b,c) = (CH + HJ)\,R$.

The fraction of the red and blue rays absorbed by the yellow prism at point $(a,b,c) = (CH + HJ)\,Y$.

The fraction of the red and yellow rays absorbed by the blue prism at point $(a,b,c) = (CH + HJ)\,B$.

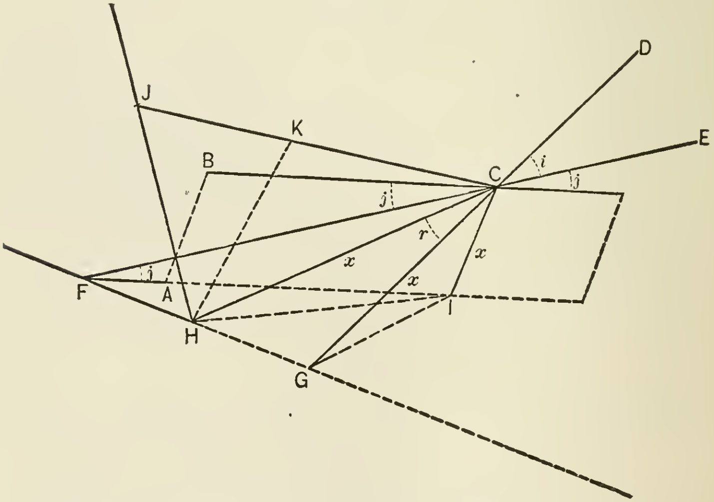
The axes of reference are taken as indicated in Fig. 1, and the coördinates of the point C are a, b, and c, where a and c are arbitrary

FIG. 1.



and b depends on a, through the relation $b = a \tan \theta$, in which θ is the prism angle.

FIG. 2.



In Fig. 2, DCG is normal to the surface ZOM (Fig. 1), the point G being in the plane ZOX.

The incident ray EC is prolonged in the plane BI, determining with CG a plane CFG in which the refracted ray CH is found.

The coördinates of the points C, H, and J are deduced, and from these the lengths of CH and HJ are written down.

The equation of the plane MOZ is

$$-x \sin\theta + y \cos\theta = 0.$$

The equations of CD are

$$\frac{x-a}{-\sin\theta} = \frac{y-b}{\cos\theta} = \frac{z-c}{0}, \text{ or}$$

$$\left.\begin{array}{c}(y-b)\tan\theta + (x-a) = 0\\ z = c\end{array}\right\}.$$

The equations of EC are

$$\frac{x-a}{0} = \frac{y-b}{\sin j} = \frac{z-c}{\cos j}, \text{ or}$$

$$\left.\begin{array}{c}(y-b) = (z-c)\tan j\\ x = a\end{array}\right\}.$$

The equations of CH are

$$\frac{x-a}{p} = \frac{y-b}{q} = \frac{z-c}{s},$$

in which p, q, and s are given by the relations

$$\cos r = -p \sin\theta + q \cos\theta,$$
$$\cos(i-r) = q \sin j + s \cos j,$$
$$0 = p \cot\theta + q - s \tan j.$$

On solving these equations the actual values of p, q, s are as follows:

$$p = \frac{\cos(i-r)\cos\theta \sin\theta \sin j - \cos r \sin\theta}{\sin^2\theta + \cos^2\theta \cos^2 j},$$

$$q = \frac{\sin^2\theta \cos(i-r)\sin j + \cos^2 j \cos r \cos\theta}{\sin^2\theta + \cos^2\theta\cos^2 j},$$

$$s = \frac{\cos j \cos(i-r) - \cos j \sin j \cos\theta \cos r}{\sin^2\theta + \cos^2\theta \cos^2 j}.$$

By making use of the relation

$$\cos i = \sin j \cos\theta,$$

these values are expressed in the following form:

$$p = \frac{\sin\theta \sin(r - i)}{\sin i},$$

$$q = \frac{\cos r \sin i - \sin^2\theta \sin(i - r)}{\sin i \cos\theta},$$

$$s = \frac{\sin r \cos j}{\sin i}.$$

Coördinates of point H are obtained by placing $y = 0$ in equations of CH,

$$\frac{x - a}{p} = \frac{-b}{q} = \frac{z - c}{s} \text{ and } y = 0,$$

$$\text{or } x = a - \frac{pb}{q},\ y = 0,\ z = c - \frac{bs}{q}.$$

The equation of plane CHJ is

$$s(x - a) - p(z - c) = 0.$$

Equations of HJ are

$$\frac{x - a + \frac{pb}{q}}{-p} = \frac{y}{q} = \frac{z - c + \frac{bs}{q}}{-s}.$$

Coördinates of J are given by

$$y = x \tan\theta,\ \frac{x - a + \frac{pb}{q}}{-p} = \frac{y}{q} = \frac{z - c + \frac{bs}{q}}{-s},$$

and are, therefore,

$$\frac{qa - pb}{q + p\tan\theta},\ \frac{(qa - pb)\tan\theta}{q + p\tan\theta},$$

$$\frac{(qc - bs) + (pc - as)\tan\theta}{q + p\tan\theta}.$$

The length of HJ is given by

$$\text{HJ} = \frac{(qa - pb)\tan\theta}{q(q + p\tan\theta)}$$

and that of CH by

$$\text{CH} = \frac{b}{q}.$$

By adding the values of HJ and CH and making use of the relation $\frac{b}{a} = \tan\theta$, the following simple expression is obtained:

$$\text{CH} + \text{HJ} = \frac{2ab}{aq + pb}.$$

From *à priori* considerations it is evident that any alteration in the value of the coördinate c will not affect the value of CH + HJ, and it is to be noted that the analytical expression for this sum is a function of the coördinate a, the value of which may be read from a millimeter scale at the time of the experiment.

The color value of a given ink-line, or its power of absorbing the red, yellow, and blue rays respectively, will be obtained in terms of the units of absorption by the standard red, yellow, and blue prisms respectively of standard white light by the following equations, in which A represents the fraction of yellow and blue rays found by experiment to be absorbed by both standard red prism and the ink-line under observation; D represents the fraction of the red and blue rays found by experiment to be absorbed by both standard yellow prism and the ink-line under observation; and E represents the fraction of the red and yellow rays found by experiment to be absorbed by both the standard blue prism and the ink-line under observation.

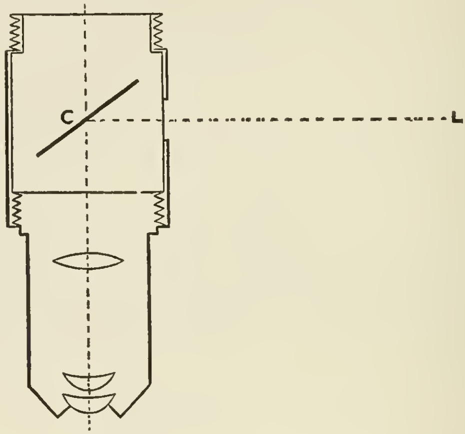
$$R' = A - (CH + HJ)\,R.$$
$$Y' = D - (CH + HJ)\,Y.$$
$$B' = E - (CH + HJ)\,B.$$

B.

The photomicrographs of pen and pencil marks (Plates IV., VII., VIII., IX., and IX a) were made with a projecting microscope of Williams, Brown & Earle, in connection with an ordinary copying or enlarging camera. The microscope was fitted with a Beck one-third inch objective, and a Williams, Brown & Earle corrected and adjustable ocular.

The most difficult part of the operation was the illumination of the paper and the mark. This was accomplished by using a Beck illuminator, the principle of which is here shown. A beam of light, L, is admitted through a side opening and strikes a circular disk, C (microscope slide cover-glass), set obliquely, as shown. A portion of the light is reflected down through the objective and is

focussed by the objective on the object to be photographed. The proper diffusion of the light is secured by means of auxiliary lenses.



C.

Extracts from a paper on

THE IDENTIFICATION OF COLORED INKS BY THEIR ABSORPTION SPECTRA.[1]

BY DR. CHARLES A. DOREMUS.

The substitution of aniline dyes for other coloring matters in the preparation of colored inks, especially red, necessitates the adoption of means for their recognition.

A characteristic feature of the aniline colors is a surface iridescence, distinguishable even in the thinnest layers.

[1] From a report of the committee appointed by the American Philosophical Society to investigate the various methods for the examination of documents. Read before the American Philosophical Society, April 10, 1896.

The beetle bronze is unmistakable. The iridescence is frequently complementary to that of the color—thus green to red.

Many of these inks also show fluorescence. This is especially developed in very dilute solutions. Highly attenuated solutions of fluorescein behave differently to light from concentrated ones. The dichroism of concentrated solutions is quite distinct from the fluorescence obtained by dilution.

Concentration appears to destroy fluorescence. This is also true of glass. Glass containing ten per cent. of uranium oxide would not be recognized as the uranium glass whose greenish yellow fluorescence is so well known.

The writer was led to investigate many of these properties in connection with a case tried in New Jersey in 1891.[1] The controversy centred on the question as to whether the ink was eosine or not. In rebuttal it was claimed that the ink was aurine. My attention had been called several years previously to the black appearance of the lips of players using rouge, one kind of which I knew to be eosine. Eosine is irresponsive to yellow rays and seems almost black in the glare of the footlights. Carmine and other reds retain more of their red color. Experiments were therefore made with different red inks, as carmine, aniline red, safranine, and eosine, and their appearance noted under monochromatic illumination of a sodium flame.

The results were not as pronounced as desired. Recourse was then had to comparing the various inks in strong daylight behind differently colored glasses. The effects were very striking, especially with the aniline inks, since they possess iridescence. Colored glasses also greatly aid in the discovery of their fluorescent qualities. The ink on the document presented a lustre when illuminated through green glass which was quite different from that of

[1] The Prerogative Court of the State of New Jersey in the matter of the Probate in solemn Form and the Last Will and Testament of George P. Gordon, deceased.

carmine and various aniline inks. The *fluorescence* of eosine may also be enhanced by the use of blue or purple glass. These experiments induced the writer to try a spectroscopic examination of inks, both in solution and in form of written characters.

A Zeiss micro-spectroscopic eye-piece and low-power lens were used at first, then a higher power.

This test is especially valuable, since the document is uninjured. It requires the brightest sunlight as a source of illumination. The ink is viewed by transmitted light and an absortion spectrum is obtained. When mapped the spectra are found to vary.

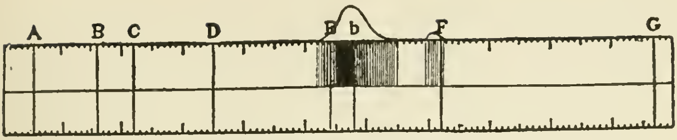
This means of identification was, however, not sufficiently developed to enable it to be used in court, nor could it be shown because of the absence of proper facilities.

At court the preliminary examination of the experts was strengthened by chemical tests applied to the ink on the document, prominently by the action of hydrochloric acid, which produced a yellow color, and by the greenish-yellow fluorescent nature of a solution of the ink.

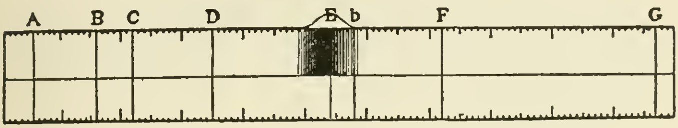
The opinion of the experts for the defence that the ink was eosine was corroborated by several ink manufacturers and a well-known importer of aniline dyes.

It was necessary to break the evidence going to prove the ink to be eosine, since that color was not discovered until 1874, eight years after the date of the will. Aurine was, however, in commercial use in 1865, and as per patent of Henry Ellis, Great Britain, No. 2267. It was not shown, however, that it was purchasable as ink in this country in 1868.

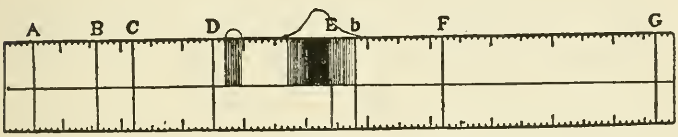
While an alkaline aurine solution produces an ink very similar to eosine in many properties and reactions, it differs widely in others, and especially in not having greenish yellow fluorescence of eosine in diluted solution and in not showing the same absorption spectrum and derivative spectra.



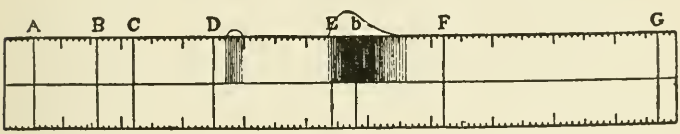
EOSINE IN WATER



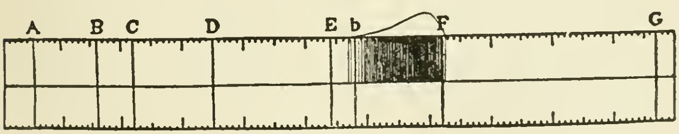
AURINE IN DILUTE ALKALI.



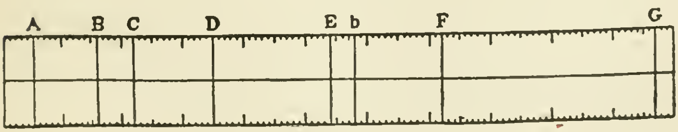
CARMINE IN AMMONIUM HYDRATE.



DAVID'S BRILLIANT CARMINE INK.



SAFRANINE.



The accompanying maps show the spectra observed with thin layers of inks. A Donné lactoscope proved very useful in varying the thickness of the layer until the most characteristic appearance was obtained. The same absorption bands were afterwards recognized when pen marks made with these inks were examined under a microscope to which a Zeiss spectroscopic eye-piece was adjusted.

The spectroscopic examination of the ink while on the document should be followed, whenever allowed, by observations of the spectra produced when the ink is subjected to the action of chemicals.

Very marked changes occur; and since even colorless solutions may show absorption bands, this means of identification possesses the double advantage of an accurate physical test without injury to the document together with a combined chemical and physical test where the application of reagents is permitted.

D.

NOTE ON PHOTOGRAPHIC TESTING OF INKS.[1]

BY S. P. SHARPLES, S.B.

On examining the writing of a certain will with the microscope, I became convinced that the alterations were, in part at least, made with a different ink. If writing is done with a thin ink such as is used in fountain pens, and which is generally made from some aniline preparation, such as induline or nigrosine, it will be found that the ink acts in a very peculiar manner. The coloring matter collects on the edges of the stroke, and these are much more intense in

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[1] From a report of the committee appointed by the American Philosophical Society to investigate the various methods for the examination of documents. Read before the American Philosophical Society, December 20, 1895.

color than the centre of the mark. The stroke may be defined as a road with a hedge on either side of it. This peculiarity is found in many other inks when they are first applied to the paper. But as the ink ages, in the case of the so-called chemical inks, the centre of the stroke becomes dark and the contrast disappears. In the case of the inks which undergo no chemical change the contrast is permanent. The examination under a microscope serves to demonstrate these points to an expert and fully satisfy him. It struck me that by the aid of a photograph I could bring out these differences. I first tried enlarging the photograph. The printer produced a good picture, but in his desire to make a good print he spoiled it for my purposes. I got him to make another trial, telling him I did not want a good picture, but one that was very much under-exposed. This brought out the differences in the ink-well. The portion written with the aniline ink had almost disappeared, except the edges of the stroke. That written with the chemical ink was almost as distinct as in the first print. I also made a number of contact prints, exposing the paper under the negative a very short time, and in this manner getting prints in which the contrast between the two inks was very marked. Lantern slides were also prepared from the negatives. These also showed the differences in the inks very plainly. In practice I would suggest that two negatives be made of the writing, a strong and a weak one ; that prints be made from each of these in the way above spoken of, that is, gradually increasing in strength, and that several lantern slides be made from the negatives in the same manner as the prints. These slides when projected on the screen will serve to bring out the differences in the inks of which I have spoken.

E.

[1] The *Chemiker Zeitung* gives the following modes of preparing fireproof inks and incombustible writing and printing paper, which appear worth attention :

A fireproof ink for use in writing on incombustible paper is made of 85.31 grams of graphite, 0.78 gram copal or resinous gum, 7.75 grams nutgalls, 31 grams indigo sulphate. This ink is black. For colored inks the graphite is replaced by earthy pigments.

* * *

[1] The best asbestos is treated with a preparation of potassium permanganate and then with sulphuric acid ; ninety-five per cent. of this asbestos is mixed with five per cent. of wood-pulp in water containing borax and glue. Another fireproof writing-ink is made by mixing Indian ink and gum with chloride of platinum and oil of lavender ; for printing-ink lampblack and varnish are to be substituted.

* * *

[1] Paper made of pure asbestos resists a high temperature without material alteration. An ammoniacal solution of nitrate of silver, colored with a little Indian ink, will preserve a legible copy when written with on the asbestos paper mentioned above and subjected to strong heat.

A free-flowing ink for writing on fireproof paper with an ordinary metallic pen may be obtained by using five parts dry chloride of platinum with fifteen of oil of lavender, fifteen of Chinese ink, and one of gum-arabic, adding thereto sixty-four of water. When the paper is ignited after being written upon with this ink, the platinum ingredient causes the writing to appear transparent, and, as a consequence, it is claimed that such writing as has become black or illegible will become readily legible again during the process of heating the paper. Colors for painting may also be made fireproof by mixing commercial metallic colors with the chloride of platinum and painters' varnish, adding an ordinary

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[1] Workshop Receipts for Manufacturers, Merchants, and Scientific Amateurs. (Second Series.) By Robert Haldane. E. and F. N. Spon, 16 Charing Cross, London ; 35 Murray Street, New York, 1883.

aquarelle pigment to strengthen the "covering power" of the color. These fireproof paints or colors can be easily used in the same manner as the common water-colors, and it is claimed they will resist the destructive influence of great heat quite as successfully as the fireproof printing- and writing-inks just referred to.

* * *

Safety-Paper.—Paper which has been passed through a solution of glue with five per cent. potassium cyanate and antimony sulphide, is immersed in a dilute solution of magnesium or copper sulphate, and afterwards dried. Nothing written on this paper with ink prepared from galls and iron salts can be destroyed by acids, etc., nor by mechanical erasing. Acids would color the black writing blue or red, while alkalies would color the paper brown ; erasing would remove the surface of the paper and show the white ground.

F.

EXPERT TESTIMONY.

Expert Witnesses.—If a single competent expert could be selected by the court to take up questions and lay his results before it, the present system would be less objectionable than it is. Nevertheless, this solution is probably not the best, because no man is capable of always observing and judging correctly, and the most careful man may be led astray by elements in the problem before him of which he does not suspect the existence. It would seem, therefore, to be fairer and less open to objection if a plan of investigation were followed which can be clearly explained to those who are to decide a case and the resulting data left in their hands to assist them in their decision.

In such a manner of presentation, if any important data have been omitted, or if the premises do not warrant the conclusion, the errors can be detected without accusing the expert of lack of good

faith, or ignorance of his subject. The fact that he has testified in hundreds of cases and in every court in the world should not be allowed to influence the jury against a logical conclusion drawn from uncontroverted facts.

A committee composed of judges of the courts in the Commonwealth of Pennsylvania was appointed to examine into the law governing the testimony of experts. The chairman, Judge Endlich, of Reading, invited the author to coöperate as a layman in settling certain preliminary questions necessary for the preparation of a sketch of a proposed law, and, first of all, in finding definitions for "expert" and "expert testimony."

In answer to this request, the following was submitted to his Honor, February, 1897:

Expert testimony may be defined as that which either rests upon the application through reasoning of principles susceptible of explanation and approved by persons of average intelligence, or is based upon the personal experience of one who is more than ordinarily qualified to discriminate between similar impressions. Testimony which does not fall under one of these two heads should not be admitted as expert testimony. It is also to be noted that the weight of expert testimony is proportional to the clearness with which the mental processes leading to a given conclusion can be followed by the hearer. Where this cannot be done, the whole force of the testimony depends upon the belief in the witness's competency and honesty.

An expert is one skilled in a subject by observation or investigation.

It will be observed that both experts and their testimony fall into subjective and objective classes.

Thus the testimony of a distinguished painter or poet as to the merit or authorship of a work of art or literature is based upon subjective impressions which may be too subtle to admit of expression, though distinctly felt. On the other hand, the testimony of a chemist that the decomposition of a certain chemical compound will require the expenditure of more energy than the value of the

product represents, reckoned in heat units obtained in the most economical way, is a conclusion based upon a train of reasoning of which every step is within the comprehension of a school-boy, though the demonstration as a whole may seem complex, and, in fact, has required centuries of experiment and reflection to evolve. Because of this character of modern applied science it seems very desirable to retain the present system of permitting each side in a court trial to employ as many experts as it pleases, but to retain an impartial expounder of the technical testimony as a friend of the court. The person filling this position will thus not be open to the objection of posing as an oracle, whose decision must be final, whether or not it has been conscientiously prepared, but he will occupy more nearly the position of a judge before whom the bibliography bearing upon the case has been cited, the dates and references given, and who, with these aids, supplemented by his own knowledge, is more likely than without them to reach correct conclusions.

It is difficult to comprehend the distinction which exists between the *subjective* expert in questions of handwriting and the person not an expert who has "seen the man write his signature," or who "is familiar with the writer's signatures," for in both cases appeal is made to the undefinable exemplar which the signature has created in the mind. In the most usual case the non-expert is richer in experience and the subjective expert in skill. The former seldom considers individual parts of a signature, but depends upon his impression of it as a whole. The latter generally dissects the signature and speaks of the peculiarities of its parts, frequently giving reasons, such as the supposed manner of holding and using the pen, etc. ; but fundamentally both proceed from the whole or dissected exemplar in the mind. As to their close connection all illusion as well as all distinction between their methods vanishes when an expert professes to be able to distinguish between genuine and false signatures at a glance.

To which the judge replied in part :

. . . The idea that, it seems to me, ought to be conveyed by a definition of expert testimony would be that "it rests either upon the application through reasoning of principles which are

generally recognized as controlling in any given science, art, or trade, by those who are practically or theoretically, or both practically and theoretically, conversant with the same; and which, while presumptively beyond the common knowledge of men, are yet susceptible of explanation to and approved by persons of average intelligence—or is based upon personal experience, etc." . . . In 174 Pennsylvania State Reports, p. 298, Judge Williams says: ". . . An expert witness is one who, because of the possession of knowledge not within ordinary reach, is specially qualified to speak upon the subject to which his attention is called." Possibly, a combination of the essential thoughts expressed in your definition and that of Judge Williams might result in something more nearly perfect than we have yet had. . . . I believe, with you, in retaining so much of the present system as puts the selection of expert witnesses (at least in the first instance) into the hands of the parties. I don't think, however, that they ought to be at liberty to call as many as they please—but only a reasonable number. . . . Your division of experts and their testimony into subjective and objective, and your notice of the blending of the two, are very good, indeed. . . .

In consequence of this first failure a second effort was made as subjoined, and this was submitted to two leaders of the Pennsylvania Bar, of whose comments brief condensations here follow. The words in brackets were stricken out by Judge Endlich.

1. *Expert.*—An expert is one who by greater power of discernment than ordinary men [either as a gift of nature, or], by reason of a greater number of previous experiences, is better able than they to elucidate a given question by observation or investigation.

II. *Expert Testimony.*—Expert testimony is that given by such a person, and is based upon his individual impressions as to the facts, *But in so far as it is possible for him to expose to persons of average intelligence the successive mental processes by means of which he attains his conclusions it is [shall be] his duty to do this: and such demonstration, however easily intelligible when thus explained, if requiring more than ordinary knowledge or skill to make it, does not lose [shall not be held to have lost] its character as expert testimony.*

27 February, 1897.

. . . Scientifically, I think very highly of your definition. I doubt, however, whether it would be accepted by the courts as a definition of what, in law, is regarded as an "expert."

In legal thought I do not think the idea of "greater power of discernment" enters. The man may start with the most ordinary powers of discernment; but if he can testify to a sufficient number of previous experiences he will be admitted. The "greater power of discernment" constitutes the *great* "expert;" but is not necessary in law to an "expert." . . .

Very sincerely yours,

John G. Johnson.

Mr. Samuel Dickson substitutes the following:

March 1, 1897.

Expert.—One having such special knowledge as to make his opinion a reasonable ground of belief.

Expert Testimony.—The opinion of an expert upon facts proven or stated hypothetically. In so far as it is possible for him to (re)state the mental processes or experimental methods by which he has reached his conclusion, it shall be his duty to do so.

The second attempt at definitions having been forwarded to Judge Endlich, together with the comments of Mr. Johnson and Mr. Dickson, he replied as follows:

March 4, 1897.

. . . I still prefer your definition of "expert" as it stands on the slip enclosed by you. The "greater power of discernment" Mr. Johnson objects to is, I think, right in association with the succeeding phrase, "by reason of a greater number of experiences." His criticism is virtually the same as that which I made upon the words "as a gift of nature." As he says, it is the previous experience that qualifies a man as an expert. Even tea-tasters, artists, and the like, are accepted as experts, not because they have naturally acute perceptions or genius in their lines, but because they are tea-tasters, artists, etc.—because that is their business or profession, or because they have made studies or experiments in those matters,—all of which implies experience. But, after all,

the ultimate reason why the latter is admitted as a basis of qualification to give opinion evidence is this,—that such experience may be presumed to have imparted a greater power of discernment in a particular branch of knowledge, etc., than ordinary men can possess. It is the ignoring of this latter element, which is a condition precedent to the admissibility of expert testimony (viz., the *subject* must be one beyond the presumptive capacity of the ordinary man), that would seem to constitute a well-founded objection to Mr. Dickson's definition. If after the word "knowledge" were inserted something like this: "on a subject beyond the presumptive grasp of ordinary man," his definition of "expert testimony" is one which suggests no need of improvement to my mind. . . . I would then define testimony and expert testimony somewhat as follows:

I. Testimony consists of the stating of facts or the production of objects, under certain guarantees of truth and genuineness, from the hearing of which statements or from the examination of which objects an inference may be drawn as to the existence or non-existence of a fact in issue or of a fact relevant to the issue. The person who states the facts or identifies the object is called the witness.

II. When the process of inference requires no other equipment than the education and experience necessary for the conduct of the ordinary affairs of life, the inference must be drawn by the jury.

III. When from facts stated or objects produced, a relevant inference may be drawn, but where the drawing of it involves such knowledge in a given sphere as results only from special study or unusual experience, the inference in such case must be drawn, not by the jury, but by one who has pursued the study or who has had the experience. The explanation of the process of inferring and the statement of the conclusion is called expert testimony, and the witness is called an expert witness.

IV. Expert testimony accordingly results in furnishing the jury with a new fact to serve as a new premise from which the jury may draw its conclusions, as in other cases. It follows that expert testimony may involve either (1) the drawing of inferences from facts which would be admissible in evidence even in the absence of expert testimony, because from such facts the jury might draw a partial inference, or (2) the drawing of an inference

from facts which would have no significance for the jury at all in the absence of expert testimony, and are therefore admissible only for the purpose of laying ground for the testimony of an expert. . . .

*　*　*

If such a problem were presented to the consideration of a body of scientific men the first thought would be to require from the witness a minute and circumstantial statement of the various facts (or postulates) on which the investigation was based; how and where they were obtained; and the successive steps of reasoning by which the conclusions were reached. The most unblushing perjurer could not stand this test,—for either his testimony would have real value, or the errors in his facts, reasoning, or method would become apparent.

But, after carefully considering the language in which these limitations of an expert were expressed, the author saw with dismay that under the existing law this definition would exclude from the category of experts any one to whom it applied, for the reason that the jury is supposed to be able to take all necessary ratiocinative steps as well as those skilled in special subjects.

The difficulty to the lay mind in comprehending this fiction of the law is that obviously, even to the most superficial observer, the greatest geniuses attain their highest fame, not so much by giving to the world what was beyond the reach of others, as by following the obscure path of consequences from a region well known to an eminence hitherto unscaled.

In fact, a large majority of the most important additions to human knowledge has consisted in demonstrations of the consequences which must follow from the existence of several isolated, but well-known facts. The putting together of these facts in a manner to show their mutual relationship and the support they give to a hitherto unsuspected conclusion is as exclusively confined to original and master minds, and is as essential to the

welfare of mankind, as any of the results of original research or new discoveries in Nature.

Can there be no expert in mathematics or in mechanical astronomy? Would Kepler, Newton and LaPlace have failed to secure this title? Yet they only put well-known facts into new relations to each other, thereby erecting new structures of old material; from which, however, immensely enlarged views of Nature were obtained. Would it be improper to call Blackstone and Coke and Kent experts in the profession they adorned? Yet, presumably, any jury of twelve men could have looked up the authorities and written the commentaries which, after all, are only the perfection of human reason—and therefore the every-day tools of the juryman.

It would seem from this that, in the present state of the law, not only is preference given to ex-cathedra utterances, without further support than the "experience" of the witness, but actually the term "expert" is confined to one who has practised the profession, or engaged in the pursuit in which the facts testified to are observed; or has been accepted previously by other courts as an "expert" on kindred subjects, no matter what his capacity may be. This method of selecting experts is good only so long as the honorable character of the witness is beyond question. On the other hand, it throws open the door to any dishonest person who may wish to earn a living by "experting;" and it is this ancient relic of a period antedating the precise methods of modern science which is responsible for the abuses of expert testimony complained of by many learned jurists to-day. As long as this antiquated view of experts endures, it is difficult to see how the canker can be eradicated.

Two courses are open: the one which naturally suggests itself to the non-legal mind, unhampered by too much experience, is to abandon the old-fashioned notion of an expert as an impediment

in the way and a useless anachronism. To such a mind it seems that there would be no greater shock to the fabric of the law by this procedure than occurred when modern civilization demanded the removal of the unnatural restrictions on the liberty of women.

G.

Handwriting Evidence in Pennsylvania.—The law in Pennsylvania applicable to expert testimony on handwriting, before the passage of the act of May 15, 1895, was very ably and fully summed up by the late Chief Justice Woodward, of the Supreme Court of Pennsylvania, May 22, 1862, in an opinion in the case of Travis *vs.* Brown, reported in 43 Pennsylvania State Reports, page 9, as follows:

1. That evidence touching the genuineness of a paper in suit may be corroborated by a comparison, to be made by the jury, between that paper and other well-authenticated writings of the same party.
2. But mere experts are not admissible to make the comparison and to testify to their conclusions from it.
3. That witnesses having knowledge of the party's handwriting are competent to testify as to the paper in suit; but they, no more than experts, are to make comparison of hands, for that were to withdraw from the jury a duty which belongs appropriately to them.
4. That test documents to be compared should be established by the most satisfactory evidence before being admitted to the jury.
5. That experts may be examined to prove forged or simulated writings, and to give the conclusions of skill in such cases as have been mentioned, and their like.

Our cases are all reconcilable with these conclusions, though the language of judges has not always been as guarded as would have been well. No doubt inconsistent authorities may be found

outside our borders, but it is not worth our while to discuss them, for if we have got a settled rule of our own it is enough for us to adhere to it, etc.

* * *

This decision prevented the expert from placing the genuine and disputed signatures in juxtaposition, and drawing the attention of the jury to their resemblances or differences, although the learned judge very truly said in the first sentence of his opinion that a comparison of one kind or another, whether it be with an actually visible pattern or with an ideal stamped upon the memory, is necessary to the formation of any judgment. It will be noted also that under clause 5 experts are permitted to give testimony as to forged or simulated writings, although under clause 2 they are deprived of the only possible means of reaching conclusions based upon characteristics of handwriting.

The incongruities of this law were only exceeded by the different interpretations it received from different judges. The following statement will illustrate this. On three successive months of the year 1894 the author was called as an expert in three different counties of Pennsylvania and in three separate cases. In each case he had prepared both composite photographs and numerical averages as the bases of his opinion. The judge of the first court in which he appeared admitted the composite photographs, but excluded the numerical averages. The judge of the second court admitted the latter, but excluded the former. The judge of the last court inquired whether the witness had ever seen any writing purporting to be by the hand of the person whose authorship of the document in litigation was disputed, and on being answered that the witness's opinion was founded exclusively on such writing, declared that under the decision of Judge Woodward, in Travis *vs.* Brown, the witness had, by the very fact of examining writing alleged to be genuine, rendered himself incompetent as an expert witness.

The inconsistency of these three decisions, and the startling consequences which were announced in the last, determined the author to make an effort to have the law changed. He accordingly prepared a sketch which, after being put into proper legal phraseology by Mr. Edward P. Allinson, of the Philadelphia Bar, and submitted to Judges McPherson and Rice for criticism, was approved by them, passed by the Legislature, and signed by the Governor, without change. The text of this, the present law, here follows :

AN ACT

Relating to the competency of experts and to the rules of evidence in questions of simulated (or altered) handwriting, declaring and defining some of the existing rules of law upon these subjects, and also extending some of the provisions of the same.

SECTION 1. *Be it enacted, &c.*, That where there is a question as to any simulated or altered document of writing, the opinions of the following persons shall be deemed to be relevant :

(*a*) The opinion of any person acquainted with the handwriting of the supposed writer.

(*b*) The opinion of those who have had special experience with or who have pursued special studies relating to documents, handwriting and alterations thereof who are herein called experts.

SECTION 2. It shall be competent for experts in giving their testimony, under the provisions of this Act, to make comparison of documents and comparison of disputed handwriting with any documents or writing admitted to be genuine, or proven to the satisfaction of the judge to be genuine, and the evidence of such experts respecting the same shall be submitted to the jury as evidence of the genuineness or otherwise of the writing in dispute.

SECTION 3. It shall be competent for experts, in formulating their opinions to the court and jury, to place the genuine and disputed signatures or writings in juxtaposition, and to draw the attention of the jury thereto ; and it shall, furthermore, be competent for counsel to require of an expert a statement of the principles on which he has based his work, the details of his work, and his opinion that the results are important to the point at issue, or the

reasoning, analysis, and investigation by which he has arrived at his opinion.

SECTION 4. The opinions of the witnesses to handwriting being submitted as competent testimony to the jury, the final determination as to whether any particular handwriting is genuine or simulated shall remain, as heretofore, a question for the jury on all the evidence submitted.

SECTION 5. All provisions of this act shall apply to all courts of judicature, criminal and civil, and to all persons having, by law or consent of parties, authority to hear, receive, and examine evidence.

Approved the 15th day of May, A.D., 1895.

DANIEL H. HASTINGS,

Governor of Pennsylvania.

H.

At a meeting of the American Philosophical Society held February 1, 1895, Dr. Persifor Frazer and Mr. S. P. Sharples were appointed a committee to report to the Society on the general subject of methods useful in the investigation of documents, with power to associate with themselves other specialists not members of the Society. The above added, as associates, Marshall D. Ewell, M.D., LL.D. (who was elected a member of the Society May 17, 1895), Dr. Charles A. Doremus, and Mr. William Hoskins. At a meeting of the committee Dr. Frazer was elected chairman. The following papers have been read before the Society as reports from this committee:

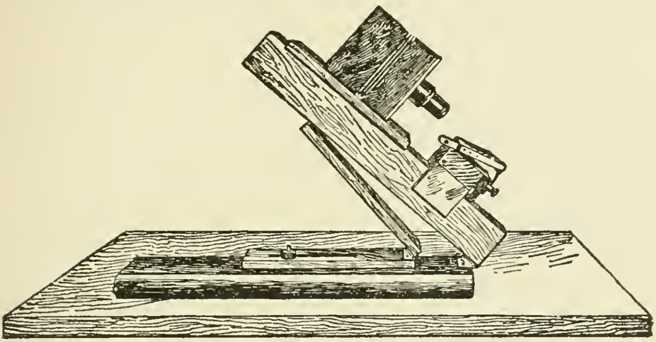
"Note on photographic testing of inks," by S. P. Sharples, and, "Evidence of the action of two hands in joint signature marks," by Persifor Frazer; on December 20, 1895. "The identification of colored inks by their absorption spectra," by Charles A. Doremus, April 10, 1896.

All of the above papers have been included in whole or in part in this book.

I.

Mr. Wingate's explanation of the method of photographing crosses placed obliquely to the axis of the camera here follows:

. . . In order to get pictures of the slides in an inclined position, after much experimentation I was forced to construct a photomicrographic camera for the purpose, with the stage of the microscope part inclinable throughout ninety degrees distally. (See Fig.) As a good microscope lens has almost no depth of



focus, it was impossible to get immediately an enlarged picture of the cross, as only one plane would be in focus at one time. Mr. Zentmayer kindly lent me a lens made on the principle of the portrait-lens of two inch equivalent focus, and I stopped it down to f. 20. With this I was able to get a fair field and a magnification of a little more than one-half diameter. From negatives made in this way lantern-slides were made by contact, and from these the larger negatives,—thus bringing the enlargement up to more than four diameters.

The direct negatives were made by daylight, facing a small window, with the stage at an angle of 8° to 11° upward inclination from the optical axis of the lens, and the whole apparatus inclined in such a way that the stage holding the slide was nearly horizontal, or inclined a little downward. . . .

HAROLD WINGATE.

PHILADELPHIA, April 19, 1894.

J.

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